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The Royal School Series.

ELEMENTARY LESSONS
IN THE
PRINCIPLES OF AGRICULTURE.

*SPECIALLY ADAPTED TO THE REQUIREMENTS
OF THE NEW CODE OF 1882.*

BY
W. JEROME HARRISON, F.G.S.,
Science Lecturer for the Birmingham School Board.



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PREFACE.



THE motto of the Royal Agricultural Society—"Practice with Science"—must be the motto of every teacher of Agriculture. The teacher must introduce as many simple chemical experiments as possible. Small collections of rocks, soils, plants, etc., should be made—a task in which the children of a day-school will render most efficient aid. After the reading of each chapter, it should be illustrated, if possible, by references to the immediate neighbourhood.

Young students dearly love "practical work;" and by inspecting the fields in walks along country lanes, the truths which form the leading facts of the science of Agriculture can be taught with a directness and vividness which will make the subsequent study of a text-book a very pleasant task.

W. J. H.

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PRINCIPLES OF AGRICULTURE.

INTRODUCTION.

I.—THE SCIENCE OF AGRICULTURE.

1. Introduction—2. Definition of Agriculture—3. Agriculture by "Rule of Thumb"—4. Scientific Agriculture—5. The Art of Experimenting—6. The Aims of Scientific Agriculture.

1. **Introduction.**—Man's reasoning powers clearly show him the necessity of making provision for the future. Other animals may be said to live "from hand to mouth," not knowing from whence their next meal is to come; but man has the foresight to prepare and store up provisions, on which to live when he cannot obtain food from other sources. It is true that a few animals act in a somewhat similar manner. The bee stores honey, and the squirrel collects nuts; but even their efforts are limited to the collection of what already exists in a wild state. The bee does not sow flower-seeds, nor does the squirrel plant nuts.

Yet there are some races of men—as the savages of Tierra del Fuego and the aborigines of Australia—who seem but little superior to the wild animals

inhabiting the same countries, in respect of their knowledge of how to cultivate the earth.

Possibly all races of men were once in the same condition as those that we now call "savage;" but by the experience gained during thousands of years, civilized nations have learned much about *Agriculture*.

2. Definition of Agriculture.—The word agriculture is derived from the two Latin words, *ager*, a field, and *colo*, I cultivate; so that, expressed as briefly as possible, it means "the art of cultivating the soil." In all civilized countries, the soil or the land belongs to some person or other, who is called the *owner*. This person may either cultivate the soil himself, or he may let it to another, in which case the owner is called the *landlord* (that is, the lord or owner of the land), and the person hiring the land is called the *tenant*.

When the cultivated land is of small extent—only an acre or so—we usually call it a *garden*, and speak of the person who cultivates it as a *gardener*; but when it includes many acres, we call it a *farm*, and the manager—whether landlord or tenant—is called a *farmer*. Some farms include only 10 or 12 acres of land, while there are a few farms in Great Britain which exceed 4,000 acres in extent.

3. Agriculture by "Rule of Thumb."—English workmen, and English masters as well, have been too much in the habit of working by what is called "rule of thumb." This means that a man has learned to do his work in a certain way, without

knowing the *reason* for what he does. It may be a very good way, or it may be a very bad one, and capable of being much improved; but the workman is not likely to hit on any method of improving it, if he does not know *why* it is bad.

Now we know that agriculture—the art of cultivating the soil—has been practised for thousands of years. It was an art held in high honour by the greatest nations of antiquity—by the Egyptians, the Greeks, and the Romans. We even have evidence that agriculture was practised long before the time of these famous nations by people to whom metals were unknown. At the bottom of several of the lakes of Switzerland there are the remains of villages which once stood on piles driven into the bed of the lake. In these Lake Dwellings there have been found specimens of cultivated plants—as wheat and the apple—which have been preserved by the charring they underwent at the time these villages were destroyed, as they appear to have been, by fire. Now all the tools and weapons found among the remains of these ancient villages are made of *stone*, mostly of the kind called flint; although we may be sure that if the people of those days had known how to obtain iron, copper, or any other metal, they would not have used stone as the material of which to make their hatchets and knives.

Thus we feel sure that men have known something about the cultivation of the soil for a very long period; but how much improvement have they made during that time? The fact is,

that the farmers of the last century were rather behind than in advance of the knowledge possessed, say, by the Romans as to the cultivation of the soil. The reason why the progress of agriculture has been so slow is that the farmers and their workmen have worked by "*rule of thumb*." Every man has done as his father did before him—has gone plodding on in the same old ways, regardless of changed circumstances.

4. Scientific Agriculture.—Many people do not understand what is meant by the word "science;" they think that anything which professes to be scientific must be hard and difficult to understand. But a great teacher has well said that "science is only organized common sense." Whenever we understand the *reason why* as well as how to do a thing, then we may be said to work scientifically. All the great advances which have been made during the present century, not only in agriculture, but in all other sciences, have been in consequence of people endeavouring to find out the reasons for the actions which they saw taking place around them. The scientific farmer is one who is able to give a just reason for his operations—one who understands the natural agencies by which he is surrounded, and is able either to take advantage of them and guide them for his benefit, or, if they are injurious, so to neutralize their evil effects as to render them harmless. In scientific agriculture we require *practice with science*. A person who had studied science only would make even a worse farmer than a labourer who had never learned science.

What is required is that all who have to do with the cultivation of the soil, or who have an interest in it, shall first be able to *do the work* in the best possible manner, and secondly understand clearly the *reasons why* the work is best done in that manner.

5. The Art of Experimenting.—An experiment is a question addressed to Nature. Look at a little child, and see how it desires to experiment on every substance by which it is surrounded,—how it tries to touch things in order to ascertain whether they be hard or soft; how it puts things into its mouth to discover their taste, and whether they are good to eat! In this way, the older the child grows the more it actually knows of the matter which composes the world on which it dwells, and the greater does its stock of knowledge or experience become. But the human mind is not content with simply noticing what takes place. It desires to inquire more deeply into many things, and wonders what would take place if certain things were to happen. Then, if it be possible, these things are made to happen; and doing this is called making an experiment. For instance, we notice that a candle burns in air, and we wonder, perhaps, whether or how a candle would burn in a space in which there was no air. Well, we *try the experiment*: we put a lighted candle into a vacuum (an empty space), and we find that it instantly goes out. Every experiment ought to teach us something; this experiment has taught us that a candle will not burn without air.

6. The Aims of Scientific Agriculture.—The farmer desires, in the main, three things:—

- (1.) The heaviest possible crops.
- (2.) That these crops should be produced at the lowest possible cost.
- (3.) That the soil should be exhausted as little as possible.

As to the best way of accomplishing these three objects, the farmer will learn much by practice and experience. Every crop put into the soil may be considered as an *experiment*; and farmers and their labourers have been experimenting in this way for thousands of years, and have handed down from generation to generation much useful knowledge. Unfortunately, however, the cultivators of the soil have not known that they were experimenting, and hence have not learned so much from their experiments as they might have done.

II.—SCIENCES WHICH RENDER ASSISTANCE TO AGRICULTURE

7. Agriculture requires Aid from other Sciences—8. Chemistry—9. The chemical Elements—10. Compounds—11. Names of some important Compounds—12. Properties of Water.

7. Agriculture requires Aid from other Sciences.—Another reason for the slow progress which has been made in the science of the cultivation of the soil, is that it requires much help from several other sciences. Now these other sciences have themselves not been developed till comparatively recent times.

There are four sciences which are especially useful to agriculturists—namely, chemistry, geology, botany, and physiology.

8. Chemistry.—Chemistry is the science which treats of the composition of matter, and of the processes by which changes are effected in its composition. Thus, if we pick up a curious heavy stone, and want to know what it is made of, it is to the chemist that we must apply for information. Or if we leave a clean, bright thin piece of iron in the open air, and in a few weeks find it changed entirely into red rust, chemistry is the science that will explain how the iron was converted into the rust.

9. The chemical Elements.—Chemists have examined all the substances that we see around us, and that form the earth on which we dwell. Air and water, rocks and soils, animals and plants, are shown by the science of chemistry to be all made of seventy simple substances, which are called *elements*. Fifty-five of these elements are metals—as, iron, gold, copper, tin, aluminium, sodium, potassium, calcium. Some of these metals are common, while others are exceedingly rare.

The remaining fifteen elements are called non-metals. They include four well-known gases—oxygen, hydrogen, nitrogen, and chlorine; the black solid called carbon, which is so familiar to us as charcoal, soot, coke, etc.; the almost equally well-known yellow solid named sulphur; a solid called phosphorus; another solid named silicon, which is very rare indeed by itself, but very common in combination with other elements. The seven remaining non-metals are of less importance to us.

It is very necessary to have a clear idea of what is meant by an element. The substances named above, such as oxygen, gold, etc., are called elements, because each of them is made of one kind of matter only, and contains no other. Thus, out of oxygen the most skilful chemist could get nothing but oxygen, and out of gold nothing but gold, and therefore these substances, and all others of which the same thing can be said, are called elements.

10. Compounds.—A substance which is made of two or more elements joined together is called a *compound*. Most of the substances we see every

day are compounds; for though there are only seventy elements, yet there are millions of compounds. We may compare the elements to the twenty-six letters of the alphabet, out of which, as we know, many thousands of words can be formed. Now just as two, three, or more *letters* join to form a *word*, so do two, three, or more *elements* join to form a *compound*: the red rust which is formed when iron is exposed to the air is a compound consisting of iron and oxygen.

11. Names of some important Compounds: (1.) *Oxides*.

—The element oxygen joins with all the other elements, singly, to form a series of compounds which are called oxides. An oxide is a compound consisting of oxygen and some one other element: thus common red rust is an *oxide of iron*. Water belongs to this class of compounds; it is composed of oxygen and hydrogen, in the proportion (by measure) of two parts of the latter gas to one of the former. Silica is another well-known oxide; it is composed of oxygen and silicon. Alumina, again, is a compound of oxygen and aluminium.

(2.) *Chlorides* are compounds of the element called chlorine, with some one other element. Thus, common salt, with which every one is familiar, is a compound of the non-metal chlorine, with the metal called sodium, and is properly called *sodium chloride*. This example illustrates the common truth that a compound has different properties from those of the elements which compose it; for sodium is a light metal, and chlorine is a yellowish poisonous gas, yet common salt is a white solid, useful as food.

(3.) *Acids* are liquid compounds, having a sour

taste, and possessing the property of turning (vegetable) blue colours red. They include vinegar, whose chemical name is *acetic acid*; also *sulphuric acid* (composed of sulphur, hydrogen, and oxygen), which is commonly called oil of vitriol; *nitric acid* (composed of nitrogen, hydrogen, and oxygen); *phosphoric acid* (composed of phosphorus, hydrogen, and oxygen); and *carbonic acid* (composed of carbon, hydrogen, and oxygen).

(4.) *Alkalies* are compounds which have opposite properties to those of acids. They restore the blue colour to substances which have been reddened by acids; so that if your coat shows red spots caused by drops of acid having been spilled on it, you should immediately rub some alkali on the place. The principal alkalies are ammonia, potash, and soda.

(5.) *Ammonia* is a gas composed of nitrogen and hydrogen. It is extremely soluble in water. The liquid sold by druggists as ammonia, or hartshorn, is really ammonia gas dissolved in water. Ammonia exists in the air, but in very small quantities.

(6.) *Potash*.—The potash, or potashes, of commerce is carbonate of potassium (being composed of carbon, potassium, and oxygen). It obtained the name of pot-ash, because it was first obtained from wood ashes—wood being then in general use, as coal is now, for heating pots and other utensils.

(7.) *Soda*.—The soda, or soda-crystals, of which we may perhaps have seen the washerwoman put a handful in the copper, is properly or scientifically called carbonate of sodium (being composed of carbon, sodium, and oxygen).

12. Properties of Water.—Of all substances water is perhaps the most essential to plants. Consisting as it does of the two elements hydrogen and oxygen, it not only supplies these to plants, but it also dissolves a great number of solid substances, which are thereby enabled to enter plants. Water may look clear, and bright, and sparkling, and yet it may contain a large quantity of (dissolved) solid matter.

Water can exist in *three states*,—namely, as a solid (*ice*), as a liquid (*water*), and as a gas (*water-vapour* or *steam*). It can readily be made to change from one state to another by adding or taking away heat. Thus, when we cool water down to a temperature of 32° , it becomes ice; and when we warm it to 212° , it changes into the gas called water-vapour or steam.

III.—SCIENCES WHICH RENDER ASSISTANCE TO AGRICULTURE

(Continued.)

13. Geology—14. Kinds of Rocks—15. Crystalline Rocks—16. Aqueous Rocks—
17. Movements of the Earth's Crust—18. Geological Maps—19. Botany—
20. Physiology.

13. Geology.—The science of geology endeavours to explain the history of the crust of the earth. By the crust we mean as much of the outside of the world as we can examine. What the interior of the earth is like we shall never know, for our deepest mines reach only to the depth of half a mile. This, however, does not concern the farmer, who is quite satisfied if geology can help him to understand the nature of the rocks which form the surface on which he walks, and of the soil in which his crops grow.

14. Kinds of Rocks.—By the term rock, a geologist understands any substance which makes a bed or layer in the crust of the earth. We believe that the earth was once a molten, liquid mass, but that, cooling down, and parting with its heat, it became solid. What the first rocks were like we do not know, since there are none of them remaining, but it is most probable that they resembled the rock which

we call lava, and which we sometimes see issue, in a liquid condition, from the craters of volcanoes.

15. Crystalline Rocks.—When we look at a piece of loaf-sugar, we see that it is composed of an immense number of little crystals adhering to one another, and reflecting the light from their glistening sides. Many rocks, too, are composed of crystals, though sometimes the crystals are so small that we cannot distinguish them without the aid of a microscope. Granite is the best known of these crystalline rocks; but there is another called syenite, and a third named trap or basalt. Granite and syenite occur (in the British Isles) only among very old rocks, as in Cornwall, Wales, the Cheviot Hills, and the Highlands of Scotland. Basalt is a later formed kind of volcanic rock well seen in the Hebrides, in Arthur's Seat near Edinburgh, and in the Rowley Hills near Dudley. These crystalline rocks were formed far down below the surface of the earth; and we know that great heat, and probably hot water too, were required to form them. Now the interior of the earth is still hot: the heat increases as we go down the shaft of any mine, so that at the depth of a few miles the temperature must be very great indeed. And it is at such a depth that crystalline rocks like granite are believed to have been formed. If they are now seen at the surface, it is because the newer, later-formed rocks which once covered them have been washed away, or because they have been thrown up by volcanic force.

Looking closely at a piece of granite, we see that it is formed of crystals of three distinct kinds:

there are hard, glassy crystals of *quartz* or *silica*; there are opaque crystals (usually of a white or red colour) of *felspar*; and there are flat plates (black or pearly in colour) of *mica*. Chemically speaking, the felspar and the mica are composed of silicate of alumina, together with some potash, soda, and lime.

16. Aqueous Rocks.—The crystalline rocks, however, form but a very small part of the surface of the earth. What other rocks do we meet with, and how were they formed?

(1.) *Sandstone*.—A common rock in many parts of the country is that called sandstone, because, as we may see at a glance, it is composed of grains of sand. If we imagine a mass of granite broken up till the crystals were separated from one another, and then all the quartz crystals (the silica) well rolled and rubbed against one another till their edges were worn off, and lastly, these grains of sand, as we may now call them, pressed together to form a hard rock, then we should get just such a rock as sandstone. This, no doubt, was the way in which the first sandstones were formed.

(2.) *Shales, Slates, Clay*.—But what would become of the crystals of felspar and of mica which we also saw in the granite, and whose chemical composition we stated to be chiefly silicate of alumina? These substances would break up into extremely fine particles or flakes, and if we mixed them with a little water, they would form a stiff mud or clay. Now the rocks we call shale and slate have been formed in a very similar way. Granite, or some other rock containing silicate of alumina, has been

broken to pieces by agencies which we shall presently describe, and the flakes of clay have all been deposited together in one place, forming a layer or bed; afterwards they have been pressed and hardened till they now form the rocks called shale, or slate, or clay.

(3.) *Limestone*.—Chalk is a very common rock in the south-east and the east of England. It there forms a bed nearly one thousand feet thick. If we



FIG. 1.—SECTION OF A PIECE OF CHALK, SHOWING SHELLS.

pour a drop of vinegar (or almost any of the acids we have named) on a lump of chalk, we shall see a bubbling up, or effervescence, which is due to carbonic acid gas escaping from the chalk. The chalk, in fact, is *limestone*, and its composition is nearly pure carbonate of lime, which is a compound of the metal calcium with carbon and oxygen. All limestones can be detected in this way, by pouring on them a

few drops of some acid. The acid, however, will have no effect on sandstone, etc. Limestone is called a *calcareous* rock, from the Latin word *calx*, lime. Many, indeed most limestones are composed of the shells or hard parts of creatures which lived in the sea. We know that a bed of limestone is now forming at the bottom of the North Atlantic Ocean. The sea-floor is there formed of a whitish ooze or mud, which under the microscope is seen to consist of innumerable tiny shells. The inhabitants of these shells lived in the water of that ocean, and when they died their shells fell to the bottom. Millions of these shells have fallen, and more are falling every minute; so that, in time, a bed of chalk of great thickness may be formed there.

Rocks like sandstone, shale, slate, clay, and limestone, which we are sure have been formed by and in water, are called *aqueous* rocks, from the Latin word *aqua*, water.

17. Movements of the Earth's Crust.—We usually think of the ground on which we walk as being immovable and unalterable; but the dwellers in volcanic regions could tell a different tale. On the western coast of South America, a tract of land 600 miles in length was raised six feet by a single earthquake. In other regions of the earth the land has been depressed; islands, for instance, have sometimes disappeared beneath the waves. Indeed, when we come to reflect on it, we see clearly that the crust of the earth must have been, and must still be, in continual motion—not a rapid motion certainly, but a slow and sure one. If we walk

round the coasts of our own islands, we shall see the sea everywhere attacking the land, the waves beating upon and breaking down the cliffs. This action alone would in time suffice to wear away all the land, and to spread its materials out, as sand and mud, on the bottom of the ocean. But an inspection of almost any quarry or any railway-cutting will show us that there must be some force at work which prevents the land from being all washed away—some force or forces of a volcanic nature which are elevating parts of the crust, while other parts are perhaps being depressed or are being washed away by water. If we examine any of the aqueous rocks, which form nearly all the land, we shall see in them the clearest evidence that they were formed underneath the water of our seas; and since they are now dry land, they must have been lifted up by some force during the course of ages. We shall find these rocks to be made of flakes of mud and grains of sand, such as we may now see lying on our shores, and we shall also find them to contain shells and other remains of once living things—*fossils*, as they are called—which are generally the relics of creatures that inhabited the seas at the time these rocks, then soft mud and sand, were being formed at the sea bottom.

18. Geological Maps.—Every farmer ought to possess a geological map, showing the rocks which lie beneath the soil of his farm. Such maps have now been made by Government officers for nearly the whole of the British Isles, and their value to the cultivator of the soil is very considerable.

19. **Botany.**—The word botany is derived from the Greek word *botanē*, which means a plant. Botany is the science which tells us all about plants; it describes their structure and the manner in which they live, and endeavours to classify them and to explain their distribution over the surface of the earth. Since agriculture is largely concerned with the growth of plants, it is clear that a knowledge of some portions of the science of botany must be of great advantage to the farmer.

20. **Physiology.**—The science of physiology treats of the structure and life of animals. If we wish to know how to keep animals in good health, or how to treat them in disease, we must study physiology. Since horses and cattle, pigs and sheep, are kept on almost every farm, it is very necessary for the farmer to know something of physiology.

IV.—MATTER AND LIFE.

21. Classification of Matter—22. Organic Matter—23. Inorganic Matter—
24. The three Kingdoms of Nature.

21. Classification of Matter.—We have seen that all the substances which compose our world are either *elements* or *compounds*. This is a chemical classification of matter. But we may also divide matter with reference to life, and then we obtain the two classes of *organic matter* and *inorganic matter*.

22. Organic Matter.—If we examine either an animal or a plant, we find that it is made up of distinct parts or *organs*, and we therefore call it an organized being. Thus a sheep has lungs, which are its breathing organs; it has a heart, the organ which makes its blood circulate; it has an organ for sight—the eye; and so on. Or consider a rose: we perceive in it organs for absorption—the root and the leaves; an organ for producing seed—the flower; organs of defence—the spines or prickles; with many other beautiful arrangements for the use of the plant. We may say, then, that everything which has life is organized. When we carefully examine these living, organized beings, we notice their beautifully rounded, swelling outlines; there

are no sharp angles or straight lines bounding their exteriors, but we have undulations or curves *instead*. Again, all organized beings are *born*. They *grow*, and they *die*. We may notice, too, that they live and grow by means of food taken into the *interior* of their bodies.

We apply the term organic, not only to matter which *has* life, but also to matter which clearly has *had* life, or has been produced by living matter. Thus we consider bone as an organic substance, although the animal to which the bone belonged may have long been dead. We call *coal* an organically formed rock, because it consists of the remains of plants which lived and died perhaps millions of years ago. Again, *sugar* belongs to the class of organic substances, because it was produced within an organized being—a plant.

23. Inorganic Matter.—How different is a lump of clay or a piece of sandstone from an animal or a plant! The minerals and soils, the water and the air, the metals and the non-metals—these have no organs, and hence they are called *inorganic* substances. They have no life, and they show no signs of ever having had any. A crystal of quartz is as good an example as we can find of an inorganic body. We notice its straight edges and flat shining sides. We see that it is alike all through, having no parts or organs. It was not born, and it will never die. It may grow; but if so, it will be by additions to its *exterior* or outside, for it takes in no food.

We shall find that in agriculture it is necessary

to understand clearly the difference between *organic* and *inorganic* matter.

24. The three Kingdoms of Nature.—Matter is very frequently classified under three heads, called Kingdoms—(1) the Mineral Kingdom, (2) the Vegetable Kingdom, and (3) the Animal Kingdom. We can easily compare this classification with that which we have just made into the *two* divisions of *organic* and *inorganic* matter.

- | | |
|--------------------------|---------------------------|
| 1. ORGANIC MATTER | { (1.) Vegetable Kingdom. |
| | { (2.) Animal Kingdom. |
| 2. INORGANIC MATTER..... | (3.) Mineral Kingdom. |

In considering the three Kingdoms of Nature, we should note that the *Mineral Kingdom* forms the basis or foundation, as it were, on which the others are built up. The members of the *Vegetable Kingdom*—plants—subsist on the mineral kingdom; deriving their food from the soil, and from air and water; taking in mineral substances, and using them to build up their tissues and organs. But the members of the *Animal Kingdom* are not able to do this. Animals cannot live on mineral food; they require it to be first prepared and changed. But this is just the work which plants are able to do; and so animals use plants as food, while many animals eat, in addition, the flesh of other animals.

The student of agriculture requires to know something about all the three Kingdoms of Nature. The soil belongs mainly to the *Mineral* kingdom; the crops raised on the soil belong to the *Vegetable* kingdom; while the creatures that consume these crops are members of the *Animal* kingdom.

PART I.

THE PRINCIPLES INFLUENCING THE SUPPLY OF PLANT-FOOD IN THE SOIL.

I.—COMPOSITION OF THE ATMOSPHERE.

25. Properties of the Air or Atmosphere—26. Analysis of Air—27. Properties of Nitrogen—28. Properties of Oxygen—29. Properties of Carbonic Acid Gas—30. Ammonia—31. Nitric Acid—32. Water-Vapour in the Air.

25. Properties of the Air or Atmosphere.—Our world is surrounded by a gaseous envelope, called the air, which reaches to a height of 200 miles, and presses on the earth's surface with a weight (at the sea-level) of 15 lbs. on every square inch. Animals and plants live at the bottom of this ocean of air, just as some fishes live at the bottom of the ocean of water.

We all know that air is necessary to life. Both animals and plants soon die if they do not get a sufficient supply of air. Air is also needful to combustion, or burning. Thus, when we want the fire to burn up quickly, we force air through it by means of a pair of bellows.

Air is a most important substance in agricultural

operations; but before we can understand how it acts, we must know something of its composition.

26. Analysis of Air.—Air is a mixture, and not a true chemical compound. If we were to take 10,000 gallons of dry air, we could obtain from it the following gases:—

	Gals.
Nitrogen.....	7,900
Oxygen.....	2,096
Carbonic Acid Gas.....	4
Ammonia.....	A trace.
Nitric Acid.....	A trace.
	<hr/> 10,000

27. Properties of Nitrogen.—The gaseous element called nitrogen, which forms very nearly four-fifths of the atmosphere, does not, when alone or uncombined, possess any very active properties. In the air it serves to dilute the oxygen, which, by itself, would be too strong in its effects on life. Nitrogen is a colourless and transparent gas. It has neither smell nor taste, and it will not readily combine with other elements. It is very slightly soluble in water.

28. Properties of Oxygen.—The gas called oxygen readily combines with almost every other element. Not only does oxygen form about one-fifth of the atmosphere, but we also find it in a great number of solid and liquid compounds. Indeed, it has been estimated that this element alone forms about one-half by weight of the crust of the earth, being thus the most abundant of all the seventy elements. When we see any substance burning, we may be certain that what we call burning is really *oxidation*,—that is, that the matter of the coal, or the candle, or the

gas, or whatever it may be, is combining with the oxygen of the air, and in the act of doing so is producing heat and light. Oxygen gas is slightly more soluble in water than nitrogen.

29. Properties of Carbonic Acid Gas.—This substance is a compound of carbon and oxygen. Chemists have a short way of writing it as CO_2 , the letter C standing for one atom of carbon, while the O_2 tells us that there are two atoms of oxygen. Thus, by writing CO_2 for carbonic acid, we are continually reminded that it is a compound of carbon and oxygen, and, further, that it contains twice as much oxygen as carbon. It may seem to us that there is a very small *proportion* of carbonic acid gas in the air, and this is quite true, for we know that 10,000 gallons of air contain only four gallons of CO_2 ; but then there is such an immense volume of air surrounding the world that the actual amount of carbonic acid gas is very great. It may be asked, Where does this CO_2 come from, and how does it get into the air? The reply is, that almost every burning body is producing, by its combustion, some carbonic acid gas. Most of the things that we burn contain carbon—coal, for instance, is nearly pure carbon—and when they burn, their carbon joins with the oxygen of the air and forms carbonic acid gas. CO_2 is more soluble in water than either oxygen or nitrogen.

30. Ammonia.—Of this powerful alkali there is so small a proportion in the air that we can only call it a *trace*. Pure ammonia is a transparent, colourless gas, possessing a very pungent smell. It is

produced by decaying animal and vegetable matter, from which it rises into and mixes with the air. Ammonia is extremely soluble in water, so that every shower of rain washes some of this gas out of the air and brings it down into the soil. Chemists represent the composition of ammonia by the letters NH_3 , since they find it to be composed of one part of nitrogen (N) to three parts of hydrogen (H). It has been calculated that there is about one gallon of ammonia in 1,000,000 gallons of air.

31. Nitric Acid.—Traces of this very powerful acid also occur in the atmosphere; but, like ammonia, it is readily brought down in the rain. It is composed of nitrogen, hydrogen, and oxygen; the proportions of each being represented by the letters HNO_3 . Since nitrogen and oxygen exist side by side in the air, we might suppose that they would chemically combine and form this acid. But they will not do so unless they are both strongly heated. Now, during thunderstorms, flashes of lightning do very strongly heat small portions of the air, and at such times a little nitric acid is formed.

32. Water-Vapour in the Air.—The table on page 29 represents the composition of dry air. But we know that the air always contains a greater or a less quantity of water-vapour, which has been evaporated by the heat of the sun from the surfaces of seas, rivers, and lakes. If we take a clean, bright, glass vessel and fill it with cold water, and then bring it into a warm room, we shall notice that the outside of the vessel soon becomes dim and moist. The cold glass chills the air touching it, and then

some of the water-vapour in the air is deposited on the glass, for cold air cannot hold as much vapour as warm air.

In 10,000 gallons of ordinary air there are about 150 gallons of water-vapour, which, if condensed, would yield about three-quarters of a pint of liquid water. Water-vapour is, of course, like water, a compound of the two gases hydrogen and oxygen. It is represented shortly by the letters H_2O .

II.—FORMATION OF THE SOIL

33. The Farmer as a Manufacturer—34. Importance of a Knowledge of the Soil—
35. What is the Soil?—36. How the Soil was formed.

33. The Farmer as a Manufacturer.—Farming has long been thought to be wholly different from manufacturing; and yet, when we consider the question fully, it seems clear that a farmer is a manufacturer just as much as a man who makes cotton goods, or broadcloth, or steam-engines. Every manufacturer has what he calls his *raw material*, out of which he makes the goods he sells. The manufacturer of calico requires raw cotton; the manufacturer of broadcloth requires wool; and the manufacturer of steam-engines requires iron, steel, and other metals.

Now, what is the raw material possessed by the farmer, and what does he manufacture out of it? His raw material is clearly the soil of his farm, although he calls, too, on the atmosphere to help him; and out of this soil he manufactures all the vegetable and animal produce which he sells.

34. Importance of a Knowledge of the Soil.—All other manufacturers have long known how important it is to study the nature, composition, and peculiarities

of the raw materials which they use. But it is only of late years that agriculturists have awakened to a knowledge of the necessity of studying the *soil*.

35. What is the Soil?—The soil is the soft, earthy matter, composed of innumerable small particles of divers substances, which everywhere forms the surface of the land, except where the bare, hard rock juts out through it. In thickness, the soil varies from a few inches to two or three feet; and as a rule “the thicker the better,” other things being equal.



FIG. 2.—Section from east to west, across the Malvern Hills. Upon the hard granite of the hills, at A, there is little or no soil, and no crops can be grown there. A rich and productive soil has been formed by the softer rocks at B and C.

Suppose we go out into our garden and dig a deep hole, how shall we know when we have reached the bottom of the soil? We can tell this by the change of *colour*, and often by a change of *texture* as well. The soil is usually darker in colour and finer in texture than the earthy matter which lies underneath it, and which is called the *sub-soil*, or under-soil. If we go on digging down through the sub-soil, we shall at last come upon the hard, solid rock. (See Fig. 3.)

36. How the Soil was formed.—There was a time when there was no soil. When the world had cooled down sufficiently for a solid crust to be formed on what was previously a liquid expanse, there would at first be no soil, but all the surface of the land would be composed of solid hard rock.

Let us imagine, if we can, the whole surface of our earth in this condition: everywhere we walk on a bare stony floor; there is no sand, no mud, no soil of any kind, but everywhere such rocks as granite and syenite and basalt form a dreary, desolate surface, on which not a plant of any kind can grow.

How long would such a state of things last? Not a very long time. If we revisited the scene

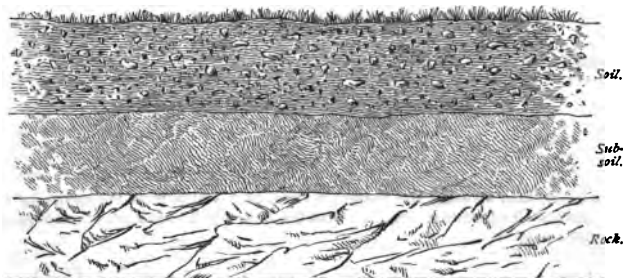


FIG. 3.—Showing passage of the soft, finely-divided soil into the harder sub-soil, and, lower still, the solid rock.

after ten years, we should detect a slight change. A century would witness a greater decay of the rocks; and in the course of a few thousand years soil of a considerable thickness would be formed.

The science of geology teaches us that millions of years have elapsed since the primitive or first-formed rocks constituted the whole of the land surface of the earth. These primitive rocks were worn away and broken up into soil. That soil was hardened again to form aqueous rocks of one

kind or other; and these aqueous rocks were again broken up to form new soils. All this has happened, not once, but many times, so that although all the rocks which now exist must have come from or have been made out of the primitive rocks, yet there have been such sortings and changings and rearrangements that the variety of rocks is now very great indeed, and we consequently have an equally large variety of soils.

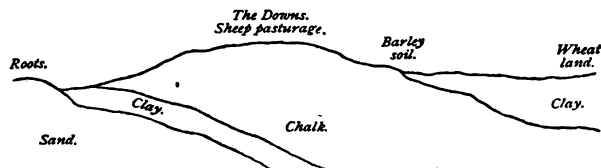


FIG. 4.—Section showing the various beds of rock which form the surface of a part of Hertfordshire, together with the crop which each kind of soil is best able to grow.

Let us roam over one of the moorlands of Derbyshire, where we may still walk on a hard sandstone or on limestone rocks uncovered by soil; or let us climb one of the hills of Wales or of the Scottish Highlands, where we shall find bare slate or granite beneath our feet. Sitting down on some projecting crag, let us consider how such hard stony masses are disintegrated, or broken up into little pieces, to form the soft earthy matter we call the soil.

III.—AGENTS WHICH HAVE FORMED THE SOIL.

37. The Atmosphere has helped to form the Soil—38. Water has helped to form the Soil—39. Frost has helped to form the Soil—40. Other Agents which have helped to form the Soil—41. Decay of the Rocks.

37. The Atmosphere has helped to form the Soil.—
Two of the gases which are present in the air are very active bodies. Their names are oxygen and carbonic acid gas. When the surface of a rock is exposed to the air, if there be any iron or potash or soda in its composition (and these substances occur in small quantities in almost every rock), the oxygen and the carbonic acid gas in the air combine with the iron, the potash, and the soda in the rock and form substances which dissolve in water, and which the next shower of rain will wash away. For instance, if we go into any granite quarry, we shall see all the joints or crevices covered with rust. This rust is an oxide of iron, which has been formed by the combination of oxygen from the air with iron from the granite. Thus these substances (besides others which are less common) are removed from any stone which contains them by the action of the atmosphere, and the surface of the

rock is left full of little holes, out of which the iron or potash or soda has come.

38. Water has helped to form the Soil.—Many of the substances of which rocks are formed are soluble in water, and when the rain-water runs over or through rocks it dissolves these substances and carries them away, and then the rock crumbles to pieces. But the water and the air act together. As the rain falls through the air it brings down

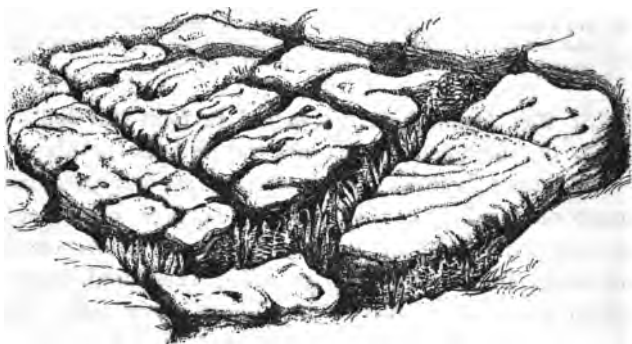


FIG. 5.—CORRODED LIMESTONE, YORKSHIRE.

with it some of the oxygen and some of the carbonic acid. The water containing these substances can affect rocks much more powerfully than perfectly pure water. Pure water cannot dissolve limestone; but when the water contains carbonic acid (as all rain-water does), it is able easily to dissolve this substance. Now, in many sandstones the grains of sand are cemented together by a little limestone: the rain-water dissolves this limy matter, and then the grains of sand fall apart and

form a sandy soil. In addition to this the very beating of the raindrops on the rocks does in time break asunder their particles. As the proverb says, "Constant dropping will wear away a stone."

The water of the sea wears away the coasts of the land. The waves act especially by using the broken pieces of rock which lie on the beach, dashing them against the cliffs and breaking off more pieces. The sand and mud formed in this way are transported by currents of water, until at last they are spread out over the floors of the seas. If, through movements of the earth's crust, these floors

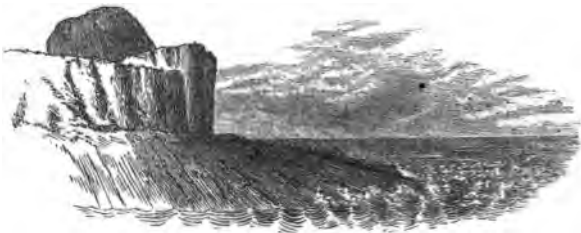


FIG. 6.—Action of the Sea on Rocks. The cliffs are being gradually worn back by the action of the waves.

were to be elevated, the new land would be found to be covered with a thick, soft soil. Often the sea heaps up in one place the matter it has removed from another. In this way has been formed the low flat tract of country, called the fen-land, which lies on the east coast of England round the Wash.

39. Frost has helped to form the Soil.—When boiling water is cooled it contracts or takes up less room. If we make the water very cold, however, we shall find that when it freezes or turns into ice

it suddenly expands. If, for instance, we were to freeze *ten* cubic feet of water, we should obtain *eleven* cubic feet of ice. In winter this expansion of water causes a great destruction of the solid rocks. Rain falls, and fills all the little holes and crevices in the rocks; then this rain-water freezes,



FIG. 7.—TALUS HEAP AT FOOT OF CLIFF.

and as it freezes it expands with irresistible force, splitting off innumerable fragments of rock. This is the reason why the base of every exposed rock is seen in spring to be surrounded by little heaps of stones. These stones represent the work done by the frosts of winter.

40. Other Agents which have helped to form the Soil.—Although air, water, and frost are the three chief agents which have formed the soil, yet they have been assisted by other agents. As soon as a very little soil is formed on a bare rock, the lowest forms of vegetation, such as lichens and mosses, commence to grow in this soil. When these lowly plants die, they decay, and their matter mingles with the soil, making it fit to grow higher orders of plants. Then the roots of these larger plants push their way into the breaking-up rocks, and help to separate the particles of which the rocks are composed.

41. Decay of the Rocks.—Dwellers in towns have the opportunity of seeing daily, if they use their eyes, how the agencies referred to above act on the hardest rocks and wear them away. It is only necessary to examine any old stone building to see how the corners of the blocks of stone have been rounded off, and how flakes have been broken away, by the action of the weather.

IV.—CLASSIFICATION OF SOILS.

42. Rock Soils—43. Rock Soils *in situ*—44. Transported Rock Soils—
45. Vegetable Soils—46. Soils vary in Character.

42. Rock Soils.—Soils which have been formed of little pieces broken from solid rocks may be called *rock soils*.

43. Rock Soils “in situ.”—If we were to dig down through the soil and through the subsoil at any place, we might expect to come on the parent rock from which the soil had been formed. In many instances this is just what we should do. For example, in most of the English counties south of the river Thames the soil has been formed from the very rocks upon which it now rests. When this is the case the rock soil is said to be *in situ*—two Latin words which mean “in place,” or “at home”—because such a soil has never been shifted, but lies where it was formed.

44. Transported Rock Soils.—Very frequently, however, especially in Scotland, and in the north of England, we find that a soil reposes on a rock which is quite different, in character and appearance, from the soil. A sandy soil, for instance, is often found

to rest on a bed of clay, and sometimes a clay soil overlies a limestone rock. Such soils are called *transported soils*, because it is clear that they have been brought from a distance.

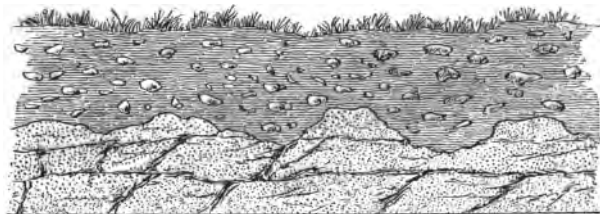


FIG. 8.—Section of a drain, showing transported soil (boulder clay) resting on sandstone rock.

Transported soils frequently cover the bottoms of valleys, or they form tracts of low, flat land along either side of a river. Generally it is water, in either the liquid or the solid state, that has formed these soils by washing them away from one place, sweeping them along, and depositing them at another. The land of Egypt is thus formed of transported soil, which has been brought down by the river Nile; and every river acts more or less in the same way.

Much of the transported soil of the British Isles is due to the action of ice, with which this country was covered at a far distant period. Rivers of ice—*glaciers*—moved over Great Britain from north to south, grinding over the rocks, breaking them up, and carrying the pieces southward, so that in the midland counties of England we often find great masses of stone—*boulders*—which have come from



FIG. 9.—ROCKS ON THE SURFACE OF A GLACIER.



FIG. 10.—BOULDER.

A rounded mass of granite, resting on a clay soil.

Scotland. Soil formed in this way is generally good soil, because it has been formed from a mixture of rocks taken from different beds.

45. Vegetable Soils.—In former days the land of this country was much moister than it is now ; for more rain fell, and there were no artificial drains, while forests spread over the surface and prevented the drying-up of the ground. Many pools or small lakes then existed, and in these pools certain water-plants—especially mosses, sedges, and rushes—grew most luxuriantly. At last they quite filled the pools in which they grew, forming what are now called *peat bogs*, while the decayed vegetable matter is called *peat*. The water has since been drained away, more or less, from these peat bogs, though many yet remain in Ireland and in Scotland. Where the peat bog was, we now have a vegetable soil formed of the peat. Such soils are usually black or brown in colour, with a fibrous and spongy texture. When ignited, they burn away, leaving about one-tenth of their weight of ash or mineral matter.

46. Soils vary in Character.—From the washing, mixing, and transporting to which soils have been subject, they are naturally of many kinds. Besides, they have been formed from different kinds of rocks. Hence the soil in one field may differ much from the soil in another field. Where two or more beds of rock meet, the soil is likely to be fertile. The soil that results from a mixture of soils derived from different rocks is almost always more fertile than soil formed by the decay of one kind of rock.

The character of a soil depends partly on its mechanical texture, and partly on its chemical composition. In order to know with certainty the character of a soil we must *analyze* it.

V.—PHYSICAL PROPERTIES OF SOILS.

47. Comparison of Soils—48. Comparative Weight of Soils—49. Absorbing Power of Soils—50. Porosity of Soils.

47. Comparison of Soils.—The character of an ordinary soil is chiefly determined by the amount of sand or of clay which it contains. It will be useful, then, to compare a sandy soil with a clayey soil, and to learn how they differ from each other.

SAND	CLAY
1. Has little cohesion.	1. Has much cohesion.
2. Is easy to plough, hence called "light land."	2. Is difficult to plough, therefore called "heavy land."
3. Does not form a paste with water.	3. Forms a paste with water.
4. Cannot be moulded.	4. Can be moulded.
5. Allows water to run through.	5. Prevents the passage of water.
6. Is gritty, friable, and hard.	6. Is soft when wet, tough and hard when dry.
7. Has little power of retaining manure.	7. Holds manure well.
8. Is firm to walk on; does not crack.	8. Is slippery when wet; cracks deeply when dry.

48. Comparative Weight of Soils.—It is so common to hear clayey soils called "heavy," and sandy soils "light," that we often mistake the sense in which the words "heavy" and "light" are then used. We are apt to think that clay is really heavier than

sand, bulk for bulk. The fact is, that if we take any vessel, and ascertain first the weight of clay which it will hold, and then the weight of sand, we shall find the sand to be considerably heavier than the clay. The usual plan is to compare the weight of one cubic foot of each substance in the dry state.

One cubic foot of dry Sand weighs 110 lbs.

"	"	Loam	"	95	"
"	"	Clay	"	75	"
"	"	Peat	"	40	"

And yet clay is rightly called "heavy," because by heavy is then meant hard to work—difficult to dig, or to draw the plough through. Sand, too, is rightly called "light," because it is light or easy to work.

The greater weight of sand is one reason why sandy soils are less damaged by treading than clayey soils. Another reason is, that grains of sand will not stick together, while particles of moist clay readily do so. For this reason sheep may be fed on crops of roots on sandy soils without damage even in wet weather, when the treading of the sheep would interfere much with the after-cultivation of a clayey soil.

49. Absorbing Power of Soils.—During hot, dry summers we may notice that certain soils are well covered with green grass, while others look dry, burnt-up, and bare. One reason of this is, that soils differ greatly in their power of absorbing moisture from the air. The air always contains water-vapour; and the hotter the air is, the more water-vapour it can contain. Thus in the height of summer there is plenty of water in the air resting

on the land. Now some soils are able to absorb much moisture from the air, and can then yield it up to the rootlets of plants. The crops on such soils may look fresh and green, while the crops on soils which possess but little of this power are parched and brown.

The following table shows the quantity of water absorbed during a night of twelve hours by 1,000 lbs. weight of each of the soils named:—

Sand	absorbs $1\frac{1}{2}$ lbs. of water.	
Loam	" 20	"
Clayey Loam	" 25	"
Clay	" 35	"
Peat	" 40	"

It is clear that the organic matter in a soil has a good deal to do with its power of absorbing moisture, since this table shows that peat, which is chiefly composed of decayed vegetable matter, absorbs by far the greatest weight of water.

50. Porosity of Soils.—We generally consider sand to be far more porous than clay; and so it is, if the *size* of the pores alone be considered. But if we reckon the *number* of the pores, we shall find many more pores in clay than in sand. The grains of sand are large, and the spaces between them—the pores—are large also; but the particles of clay are so small that we cannot see them without the aid of a microscope, and therefore the pores in clay are small also. The water cannot easily run through such small pores, so that clay is used to line the bottom of ponds, or to prevent the passage of water. But if we give the water time, it will slowly pass,

or percolate, through clay. Because of the greater number of pores, clay can hold much more water than sand: it is found by experiment that while 100 lbs. weight of sand can soak up only 25 lbs. of water, 100 lbs. weight of clay can soak up 70 lbs. of water.

The small size of the pores in clay seems to enable this substance to hold or retain any liquid better than sand can do. We all know that sand dries up more quickly than clay, allowing the water in its large pores to evaporate easily. All kinds of plant-food, too, are retained better by clay than by sand, for the fertilizing matter adheres to the tiny particles of clay better than to the larger grains of sand. The consequence is that more good results from the application of manures to clay than to sand, especially in wet seasons, since water is able to wash manure away from sand far more easily than from clay.

VI.—ANALYSIS OF SOILS.

51. Mechanical Analysis of Soils—52. Chemical Analysis of Soils—53. Separation of Organic from Inorganic Matter—54. Inorganic Substances which form the Soil—I. Insoluble in Water or in Weak Acids: Silica—55. Alumina—56. Silicate of Alumina—57. Phosphate of Lime—58. Oxides of Iron.

51. Mechanical Analysis of Soils.—Suppose that a farmer wishes to know whether the soil of a field is a sandy soil or a clayey soil, how is he to find out exactly how much of each material—how much sand and how much clay—the soil contains?

To do this he must make what is termed a mechanical analysis of the soil. Taking a spadeful of soil from five or six different places in the field, the farmer must mix these together so as to get a fair *average* specimen of the soil. Next he must riddle some of this soil, passing it through a sieve with meshes about one-eighth of an inch apart, so as to separate the stones from the fine material. A given weight of the fine earth—say, 1,000 grains—must now be taken and soaked well in water. It may even be boiled with advantage, for boiling separates the flakes of clay from one another. The mixture of soil and water must be stirred up well, and the muddy water poured into another vessel; then more water must be added to the soil

which remains. It must be again stirred up, and the water poured away into the second vessel. In this way we can separate the sand from the clay; for the sand is so heavy that it sinks to the bottom directly after being stirred up, while the particles of clay float, and are poured away, with the water, into the second vessel. Then by drying and weighing each substance we can tell exactly how much sand and how much clay the soil contains. A soil which is composed of nearly equal weights of sand and clay is termed *loam*.

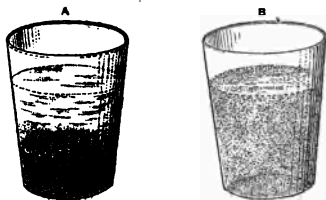


FIG. 11.—A, Tumbler containing sand and water. B, Tumbler containing clay and water. Each is supposed to have been shaken up, and then allowed to stand for five minutes.

If there are three parts of sand to one part of clay, it is called a *sandy loam*. A *clayey loam* consists of three parts of clay to one part of sand. Clayey soil which contains about one-tenth of its weight of lime is called *marl*. If as much as one quarter of the soil be lime, it is called a *calcareous* soil.

52. Chemical Analysis of Soils.—It is comparatively easy to take to pieces or analyze a soil *mechanically*; but to analyze a soil *chemically* is a very difficult process, which no one can accomplish who has not devoted much time to the study of chemistry.

53. Separation of Organic from Inorganic Matter.—The organic part of the soil can be got rid of by burning. If we take a given weight of soil, and heat it strongly in a small earthen pot or crucible, all the organic matter in the soil will burn, and will pass off into the air. By weighing the part which remains, we can tell how much organic matter the soil contained. In good

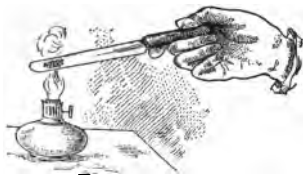


FIG. 12.—Proving the presence of organic matter in a soil, by burning a little soil on the end of a knife over a spirit-lamp.

soils it usually amounts to about one-twentieth of their weight. As a rough experiment, we may heat a little soil on a knife-blade, and notice how much of it burns away: the burning away of the organic matter will generally

leave the soil lighter in colour.

54. Inorganic Substances which form the Soil.—I. Insoluble in Water or in Weak Acids : (1.) Silica.—This is the substance of which sand, quartz, glass, and flint are made. It is composed of the elements silicon and oxygen. Silica is quite insoluble in water, and is therefore of no use to plants as food, for no substance can enter a plant unless it be first dissolved in water. It is true that silica is found in many plants—as in the straw of wheat—but it did not enter these plants as pure silica.

55. (2.) Alumina.—This is a compound of the metal aluminium with the gas oxygen. We do not find alumina by itself in the soil; it is always combined with silica. No alumina can be detected in the

plants of which our crops consist, and so we might think that this part of the soil is quite useless to plants. But we must remember that the soil has other uses besides that of feeding the plant: it serves to fix the plant, to afford it support, or a place on and in which to grow; and this the alumina helps to do. It is also believed that the alumina is useful in aiding other substances to enter plants, although it cannot do so itself.

56. (3.) Silicate of Alumina.—Pure clay, like that used for making pottery, is chemically known as silicate of alumina, because it is composed of silica and alumina combined with each other. Being, like silica, insoluble in water, it is of no direct use as plant food. Most clays, however, are not pure, but contain small quantities of other substances, on which plants can feed.

57. (4.) Phosphate of Lime.—This is a compound formed of phosphoric acid and lime. When there are three parts of lime joined with one part of the acid, it is called the *tri-calcic* phosphate of lime (from the Latin *tres*, three, and *calx*, lime). Phosphate of lime is sometimes called bone-earth, because it forms the greater part of the ash left when bones are burned. It is also contained in very small quantities in many rocks, and in large quantities in one or two thin beds of rock. It is not altogether insoluble in water, but it dissolves slowly and with difficulty.

58. (5.) Oxides of Iron.—Two compounds of iron and oxygen occur commonly in the soil. The lower oxide of iron contains equal parts of iron and oxygen;

it gives a yellow colour to the soil, and seems to act injuriously on plants. But the higher oxide of iron, which has three parts of oxygen to two parts of iron, and is of a red colour, is a very useful substance in the soil. Fortunately it is possible to change the lower oxide into the higher one. When the soil is exposed to the air, more oxygen combines with the lower oxide, and raises it to the state of the higher oxide.

VII.—ANALYSIS OF SOILS.

(Continued.)

59. Inorganic Substances—II. Soluble in Water or in Weak Acids—60. (1.) Double Silicates—61. (2.) Nitrates—62. (3.) Phosphates—63. (4.) Carbonates—64. (5.) Sulphates.

59. Inorganic Substances—II. Soluble in Water or in Weak Acids.—Many inorganic substances which will not dissolve in pure water are soluble in water which contains a little acid. Thus limestone is not dissolved by pure water, but it is dissolved by rain-water, for the latter always contains a little carbonic acid, which it has obtained in falling through the air. Moreover, rain-water frequently contains a little nitric acid, also obtained from the air. As soon as this nitric acid enters the soil it will endeavour to join with some substance in the soil in order to form a compound called a *nitrate*. Most of the nitrates are soluble in water, and they form excellent plant-food.

60. (1.) Double Silicates.—Silica can join with alumina and with another substance *at the same time*, the three bodies, when united together, forming what is called a double silicate. Thus we have silicate of alumina and soda, consisting of silica, alumina, and soda. In the same way we have a silicate of

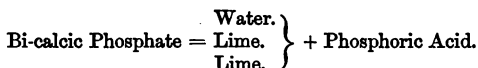
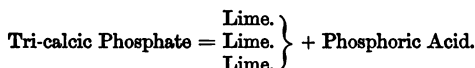
alumina and lime, a silicate of alumina and potash, and a silicate of alumina and ammonia. These are the four double silicates the presence of which is so useful in the soil.

These double silicates are more or less soluble in rain-water. The water, soaking through the ground, dissolves a little of any of these double silicates which the soil may contain; and then the roots of plants absorb this water, thus getting not only the water, but the substances which are dissolved in it. This is the way in which silica enters plants. Of the four double silicates, the silicate of alumina and ammonia is the most valuable, because ammonia contains nitrogen, an element highly needful to healthy plant-growth. Fortunately, the silicate of alumina prefers ammonia to soda, to lime, and to potash; and it will separate from any one of these three substances in order to join with ammonia, if the latter be at hand.

61. (2.) **Nitrates.**—When the nitric acid, washed out of the air by rain-water, enters the soil, it combines with any potash and soda that may be present, and forms compounds called *nitrate of potash* and *nitrate of soda*. These nitrates are soluble in water, and in this way they enter the rootlets of plants.

62. (3.) **Phosphates.**—We have learned that phosphoric acid can combine with *three* parts of lime, but that this *tri-calcic phosphate* is but slightly soluble in water, and therefore is not useful for plant-food. But when this tri-calcic phosphate is exposed to the action of air and water, it loses one

part of lime, and becomes *bi-calcic phosphate*, which is slowly soluble in water.



It is clearly the interest of the farmer to assist, as far as he can, in changing the first kind of phosphate into the second.

63. (4.) **Carbonates.**—(a) *Carbonate of lime* is well known as limestone or chalk. It consists of carbonic acid combined with lime. It is slowly dissolved by rain-water, which is then called *hard*. When hard water is boiled, the carbonate of lime settles down on the sides and on the bottom of the kettle, forming a coat or incrustation called *fur*. Sometimes the pipes through which very hard water runs get quite stopped up by the deposit of carbonate of lime.

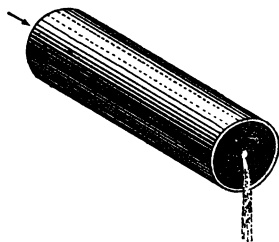


FIG. 13.—Drain-pipe nearly stopped up by a deposit of carbonate of lime from hard water flowing through it.

(b) *Carbonate of iron* gives a bluish tinge to the soil. (c) *Carbonate of magnesia* also occurs in many soils. A little magnesia is probably useful in aiding plant-growth, but the presence of a large quantity of this substance seems to be injurious.

64. (5.) Sulphates.—Sulphuric acid would be, by itself, far too strong in its properties to do any good to plants. It would, in fact, char or burn any vegetable substance, just as any strong acid burns holes in our clothes when we spill it on them. But when sulphuric acid is combined with other substances it forms compounds called sulphates, the properties of which are much milder, and which may be useful for plant-food.

(a) *Sulphate of lime* is composed of sulphuric acid and lime. It is commonly called gypsum.

(b) *Sulphate of soda* is also found in some soils.

In addition to the five classes of soluble inorganic substances we have now named, small quantities of several other substances occur, some in one kind of soil, some in another.

VIII.—ANALYSIS OF SOILS.

(Continued.)

65. Examples of Soils—66. Table of Soils—67. What the Chemical Analysis of a Soil teaches—68. Analysis of the Rocks from which all Soils have been derived—69. Table of Rocks.

65. Examples of Soils.—It will now be interesting to consider some analyses of soils which have actually been made by skilful chemists. Although these do not show the different natures of the substances in the soil, or how much plant-food it contains, yet we may learn much from them.

66. Table of Soils.—The following table gives the amount of each of the substances contained in 1,000 lbs. weight of each of the six soils named:—

	Fertile Soil.	Rich Clay.	Good Loam.	Moorland Soil.	Barren Sand.	Limestone Soil.
Insoluble silica (in clay)	586	661	645	...	...	2
Insoluble silica (as sand)	...	...	200	815	960	...
Soluble silica.....	23	...	...	...	...	...
Potash.....	10	28	8	1	...	...
Soda.....	20	14	15	...	...	...
Ammonia.....	1	...	...	...	...	...
Lime.....	41	8	13	1	...	522
Magnesia.....	1	10	11	...	...	3
Higher oxide of iron....	90	49	34	4	5	14
Lower oxide of iron....	4	...	...	3	15	7
Lower ox. of manganese	3	...	...	...	...	5
Alumina.....	14	141	36	8	5	1
Phosphoric acid.....	5	2	4	1	...	...
Sulphuric acid.....	9	1	1	...	...	...
Carbonic acid.....	61	...	9	...	...	446
Chlorine.....	12	...	...	...	...	...
Organic matter.....	120	86	24	167	15	...
Pounds.....	1000	1000	1000	1000	1000	1000

67. What the Chemical Analysis of a Soil teaches.—

Looking at these figures, we see that the most fertile soil contains the greatest variety of ingredients, and that it has by far the largest amount of those substances which are really able to act as plant-food, including soluble silica, potash, soda, ammonia, the three acids, and organic matter.

The rich clay appears to be deficient in soluble silica and in acids. The loam would probably produce rather better crops than the clay, since it is richer in phosphoric and the other acids, while the admixture of sand would make it easier to work. The moorland soil is evidently a mixture of sand and peat. The barrenness of the sandy soil is due not only to the insolubility of the silica, but to the presence of a large amount of the lower oxide of iron. The calcareous or limestone soil is clearly composed of carbonate of lime, the substance which would result from the combination of the lime and carbonic acid, of which we see that it is all but entirely composed.

Each of these six soils is supposed to have been perfectly *dried*, or freed from water, before the analyzing process was begun.

These analyses also show us what soils we may hope to render fertile by cultivation. It is plain that the barren sand and the moorland soil do not contain the elements of fertility. Of themselves they could never grow good crops, although they might be made to do so by the addition of manures. In the loam, clay, etc., there is, on the contrary, a great reserve of matter, which, by

proper methods, might be converted into a fertile state.

68. Analysis of the Rocks from which all Soils have been derived.—If it be true, as has already been stated (p. 34), that all soils have been formed by the breaking up of crystalline rocks, either directly or indirectly, then we ought to find that these rocks are composed of the same materials as form the soil.

An analysis of three of the most common crystalline rocks—granite, syenite, and basalt or trap—shows that just the same substances form these rocks as form our soils, so that we may well believe that the latter have come from the former.

69. Table of Rocks.—The following table shows the chemical composition of 1,000 lbs. weight of granite, of syenite, and of basalt:—

	Granite.	Syenite.	Basalt.
Silica	680	650	440
Potash	14	34	12
Soda	22	38	25
Lime	24	40	120
Magnesia	40	11	72
Oxide of Iron	55	47	152
Oxide of Manganese ...	5	1	3
Alumina	160	179	176
Pounds	1000	1000	1000

Of these three rocks, it is certain that the trap rock, or basalt, would by its decomposition produce the most fertile soil.

IX.—THE ORGANIC MATTER IN THE SOIL.

70. Amount of Organic Matter in the Soil—71. Appearance of Organic Matter—
72. Origin of the Organic Matter in Soils—73. Nature of Humus.

70. Amount of Organic Matter in the Soil.—As has already been said, all good soils contain a certain amount of organic matter: in 100 lbs. of good ordinary soil there may perhaps be 5 or 6 lbs. weight of organic matter. Peaty soils, of course, contain a great deal of organic matter—perhaps 90 lbs. weight out of every 100—but they form an exception.

71. Appearance of Organic Matter.—The organic matter in a soil is usually of a dark or nearly black colour. This is probably due to the fact that all organic matter contains much *carbon*, which in its most familiar forms (as soot, charcoal, etc.) is naturally black.

72. Origin of the Organic Matter in Soils.—All the organic matter in a soil once formed part of or was produced by some organized being, either an animal or a plant. The roots of dead plants, for instance, remain in the soil, and slowly decay, turning brown or black as they do so. Then the leaves and branches of trees fall to the ground

and decay. Even the trees themselves die at last, and their matter mingles with the surface-soil. The animals too, not only the large ones which roam over the ground, but the thousands of minute creatures—the insects, the worms, the shell-dwellers—that live partly *on* and partly *in* the soil, all these die, and their remains decay and mingle with the soil, which is thereby fertilized. Worms are especially useful in breaking up and enriching the land. Dr. Darwin, the great naturalist, has shown that the rich mould of our grass-lands has all passed through the bodies of worms, and has thereby been made into a fine powder, enriched with organic matter, and very much improved for the purposes of cultivation. The farmyard manure, which is added to cultivated soils, always contains much organic matter. Sometimes the land is allowed to remain in grass, or green crops are grown and are ploughed into the land, in order that the vegetable matter may decay and enrich the land by adding to the supply of organic matter which it contains.

73. Nature of Humus.—It is necessary to have a general name for all the organic matter which exists in the soil; and to the black or brown substance, which is the result of the decomposition of organic matter, the name of *humus* is applied.

This humus consists mainly of three organic acids combined with ammonia. The organic acids are called—humic acid (from *humus*, the ground), ulmic acid (from *ulmus*, an elm), and geic acid (from *ge*, the earth). They are all three composed of carbon,

hydrogen, and oxygen, in varying proportions; and when exposed to the air they readily break up, or decompose into carbonic acid gas and water. Thus the organic part of the soil is able to yield to the plant ammonia, carbonic acid gas, and water. Now these are three of the most important food-substances required by our crops, so that the presence of a moderate amount of humus in the soil will certainly add to its fertility.

The black or dark colour of humus is also useful to the soil, since the rays of the sun are better absorbed by dark-coloured than by light-coloured substances; dark soils will consequently become warm sooner than white or chalky soils. This may be proved by spreading pieces of different coloured cloth on the surface of snow: the snow will melt most rapidly underneath black cloth; showing that black absorbs the most heat.

X.—THE DORMANT AND THE ACTIVE PART OF THE SOIL

74. Value of Chemical Analysis—75. What the Farmer should know about the Chemical Composition of the Soil—76. The Dormant Part of the Soil—77. The Active Part of the Soil—78. How to analyze the Soil chemically—79. Result of the Analysis.

74. Value of Chemical Analysis.—Many years ago, when men first endeavoured to study agriculture scientifically, it was thought that a single chemical analysis of the soil, showing exactly the different substances of which it was composed, and how much there was of each, would be of the utmost value to the farmer. It was believed that such an analysis would tell the farmer in what kinds of plant-food his soil was *rich* and in what kinds it was *poor*, so that he would know exactly what manures to select in order to supply the deficiency.

But experience has shown that this kind of analysis is useless to the agriculturist. The analysis showed, perhaps, that there was an abundance of *silica*; and yet the farmer found that crops such as wheat, which require much silica, would not grow on the land. Perhaps the general analysis of the soil showed that it was rich in *phosphate of lime*; and yet the farmer knew that it was poor

grass-land, requiring the addition of phosphate of lime to make it into good pasture.

75. What the Farmer should know about the Chemical Composition of the Soil.—The fact is, the farmer does *not* want to know the entire composition of the soil only. The greater part of the soil simply serves as an anchor to fix the plant, and only a very little of it is able to act as a source of nourishment. The farmer wants a double analysis of the soil. First of all, he requires the soluble portion of the soil to be separated from the insoluble; and then he wishes to be informed of the chemical composition of each of these portions.

76. The Dormant Part of the Soil.—The term dormant, which means sleeping or resting, is applied to that part of the soil which is not ready for immediate use as plant-food. It includes all that portion of the soil which is not soluble in rain-water, or in rain-water containing a little acid. This is by far the larger part, and consists of silica, the silicate of alumina, the oxides of iron, the (tri-calcic) phosphate of lime, etc. No substance can be taken into a plant unless it is first dissolved, for solid particles are far too large to enter into the rootlets of plants.

77. The Active Part of the Soil.—This includes all those substances in the soil which are ready to dissolve in rain-water, or in rain-water aided by weak acids. It is on the nature, variety, and amount of the active part of the soil that the fertility of the land depends. We all know that for an animal to live and grow we must supply

it with plenty of food, and with food of the right kind. It is just the same with plants; food is as necessary to them as it is to animals. The active part of the soil is composed of the double silicates, the nitrates, the sulphates, the carbonates, and some of the phosphates, as well as of the humus or organic matter in the soil.

78. How to analyze the Soil chemically.— The analysis of soils is a very difficult operation to perform accurately. All that we can do here is to point out the *kind* of analysis that is required, and the *order* in which the various processes should be performed.

(1.) The sample of soil taken should be carefully *dried* at a temperature of not above 300° F.; and a portion of it should then be *weighed*: let the weight taken be, say, 1,000 grains.

(2.) Lay the 1,000 grains of dried soil on an iron plate, and carefully heat the iron to redness. This will burn away all the organic matter in the soil: it may amount, say, to 30 grains.

(3.) Place the remaining 970 grains of dried and burnt soil in a glass vessel, and pour on it a pint of boiling rain-water; shake up well; allow to stand, and pour off the water. Now, evaporate the water to dryness, and weigh the cake of solid matter which is left. This will show the weight of soil dissolved and removed by the rain-water: it may amount, perhaps, to 20 grains.

(4.) To the 950 grains of soil remaining add another pint of rain-water which has been made sour to the taste by the addition of a little acid;

shake up; allow to stand, and pour off the liquid portion. Evaporate the liquid, and weigh the cake of solid matter which remains: it may amount to 100 grains.

79. Result of the Analysis.—We thus find that the dried soil consists of:—

	Grains.
Organic Matter.....	30
Matter Soluble in Rain-Water	20
Matter Soluble in Water and Weak Acid	100
Insoluble Matter.....	850
Total.....	1,000

This shows how large a portion, even of a fertile soil, such as the above would probably be, consists of insoluble or dormant materials. There are evidently only 50 grains' weight out of the 1,000 grains' weight of soil on which we could rely as plant-food. Another 100 grains might, under favourable conditions, also become dissolved, and so help to feed vegetation; but by far the greater part of this fertile soil—850 grains out of 1,000—is totally useless to the plant as food, so long as the substances composing it remain in the state in which they now exist.

The analysis of our 1,000 grains of soil has shown us, then, that it consists of—

	Grains.
Active Matter	50
Dormant Matter.....	950
	1,000

XI.—HOW TO CHANGE DORMANT INTO ACTIVE MATTER.

80. Use of the Dormant Matter in the Soil—81. How to Change Dormant into Active Matter—82. Fallow Land—83. Virgin Soil.

80. Use of the Dormant Matter in the Soil.—We have said that the insoluble or dormant matter, which forms about nine-tenths of the soil, is useless as plant-food. It is of service, however, in affording a home to the plant—in enabling the plant to fix itself, so that the wind cannot blow it about from place to place. Moreover, the dormant matter is a storehouse for air, and for water, and for other fertilizing substances which fill its pores. It holds these ready for the use of plants, and readily yields them up to the rootlets when the latter come in search of them. But the chief use of the dormant matter is to act as a *reserve* of plant-food. It is impossible, fortunately, for the most greedy or careless farmer so to exhaust the soil that it shall ever afterwards be useless. He cannot take the dormant matter of the soil away in his crops, for it is not ready to enter them, but it remains to furnish a store of plant-food for future years.

81. How to change Dormant into Active Matter.—

Is it possible to make the dormant matter of the soil into active matter, to change the insoluble compounds into soluble ones? How can we get the silicate of alumina, for instance, to change into a *double* silicate, or the almost insoluble tri-calcic phosphate of lime to become the more soluble bi-calcic phosphate? Is it possible to get the lower oxide of iron, which tinges the soil yellow, and is positively injurious to plants, to combine with more oxygen to form the higher oxide, which will either supply plants with oxygen or will readily change into carbonate of iron, becoming then able to supply iron to the plant?

It is at this point that a knowledge of the total chemical composition of the soil becomes of real value. Unless the soil contains, in some form or other, the substances required by plants, it will be hopeless to expect it to produce good crops. It may be possible to add to the soil all that it requires; but if we have, say, a soil composed of pure sand (silica), the soil itself cannot help us much in furnishing a supply of plant-food. But if the chemical analysis shows us that the soil contains all, or most, of the compounds required by plants, then it does not matter that they are not all in the active state; we may hope that those compounds which are now dormant may in some way or other be made to become active.

82. Fallow Land.—It has long been known that if used-up or exhausted land were allowed to lie idle, without any crops being grown on it, it would generally “come round,” or become fertile once more.

By the Hebrew law, the land was to lie fallow every seventh year ; and the same practice has been carried out more or less by all civilized nations. But whence, and how, does the land get an increase of fertilizing substances during the time that it is lying fallow ? The answer is that these substances are contained in the land itself, and that they are changed from the dormant to the active state mainly by the influence of the atmosphere.

When rain-water runs through a soil, it can act only on the *outside* of the particles ; but frost goes on breaking up the particles as they lie in the soil, and so there is a larger surface for the water to act upon. As an example of this we may think of a lump of soil of the size of one cubic inch : it will have a surface of six square inches. Now break this lump in half, and its surface will equal eight square inches ; and so the more finely a particle is powdered up, the greater is the area of its exterior, the larger is its surface. Then the rain-water contains oxygen dissolved in it, and carbonic acid gas, and ammonia. These substances combine chemically with other substances in the soil, altering their composition, rendering them soluble in the water, and consequently enabling them to be taken in by the rootlets of plants.

The farmer may supply plants with food by purchasing manure and mixing it with the soil ; but he should always remember that his soil may be to him an inexhaustible source of plant-food, if he will but allow full play to the agencies of nature—the frost and the heat, the air and the rain. These

are "kindly helpers," always ready to aid us if we will but let them. Our aim should be to admit them to the soil as freely as may be, so that they may carry on their useful work as rapidly as possible. Night and day they will work for us without pay and without trouble.

83. Virgin Soil.—Soil on which no crops have ever been grown is called virgin soil. Nearly all the soil of America was in this condition at the time of its discovery by Columbus. This virgin soil may be naturally fertile, or it may be barren. If it is fertile, it must contain an ample supply of plant-food. Those who are the first to farm a tract of good virgin soil in the United States find that their crops grow perfectly without the aid of any manure. After a few years, however, the crops begin to fall off, the fact being that the plant-food in the soil is getting used up. When this is the case, if the farmer were to allow the land to lie uncultivated, and fully exposed to the weather, for a few years, he would again be able to obtain good crops from it. During the period of idleness much of the dormant matter in the soil would have become active, and would be thus ready to supply plants with the nutriment which they, as well as animals, require for vigorous growth. Generally the farmer finds that it pays better to add manure to the land than to allow it to remain "fallow." Indeed, under good and scientific farming, the soil grows *more* instead of *less* fertile.

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PART. II.

THE NECESSITY FOR CULTIVATION.

XII.—THE OBJECTS OF CULTIVATION.

84. Why we cultivate the Soil—85. How Cultivation increases the Fertility of the Soil—86. Ploughing—87. The Spade—88. The Grubber or Cultivator—89. The Clod-Crusher—90. The Roller—91. The Harrow.

84. Why we cultivate the Soil.—It is probable that at one time, long, long ago, men lived entirely upon wild fruits and wild animals. But as the numbers of human beings increased, and as civilization advanced, it was found that the ground brought forth better fruit and more fruit when it was cultivated.

We know that growing plants get their food partly from the soil and partly from the air. But the supply of plant-food in the soil, in a condition ready for use, is only limited ; so that when plants have fed on a soil for a number of years, the plant-food is all “eaten up,” and then that soil cannot produce good crops.

Now the object of cultivation is to increase the amount of plant-food in the soil, and so to prepare

the soil that the plants shall not be hindered from getting their food.

85. How Cultivation increases the Fertility of the Soil.—By draining the land, by stirring it deeply, by breaking it into small pieces, and by turning it over so as to expose the subsoil to the action of the air and of rain, we convert a portion of dormant into active matter, changing it from the insoluble to the soluble state, and thereby enabling it to enter the plant, dissolved in water. Let us consider some of the ordinary operations which are carried out on a farm, in order to see what effect they have on the soil.



FIG. 14.—PLOW.

86. Ploughing.—An ordinary plough consists of a stout steel or iron blade (called the share, the mould-board, or the coulter) set in a framework of wood or of iron. This is pulled by two or more horses, and guided by a ploughman. The blade of the plough turns over the soil, and so exposes a fresh surface to the action of the atmosphere.

When it is desired to work the ground more deeply, a *subsoil plough* is used. This can be made either to stir the subsoil only, to a depth, say, of eighteen inches, or it can be made to bring up some of the subsoil, and leave it at the surface to be acted on by the air. The subsoil may contain substances

which are injurious to plants ; but if we bring to the surface only a little subsoil at a time, and leave it

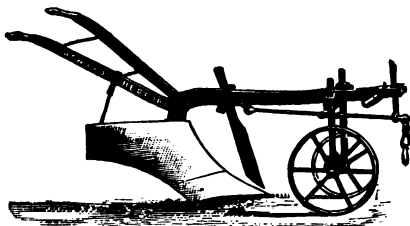


FIG. 15.—SUBSOIL PLOUGH.

long enough before the crop is sown, we shall find that these harmful substances have been rendered harmless, and even useful, by the action of the atmosphere.

87. The Spade.—Cultivation by the spade, or spade-husbandry, as it is called, is even more effective than ploughing, because it stirs the soil more deeply and more thoroughly. It is, however, much more expensive.

88. The Grubber or Cultivator.—This instrument

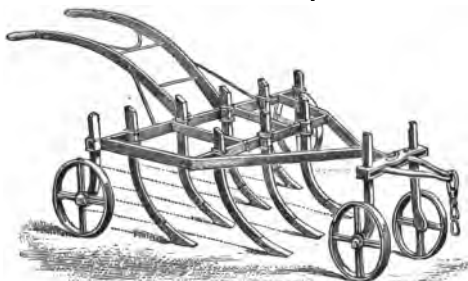


FIG. 16.—GRUBBER OR CULTIVATOR.

has long, sharp, curved tines or chisels made of steel. It is used to stir the soil deeply without

bringing the subsoil to the top. It is also very useful in removing deep-rooted weeds, such as twitch or couch grass.

89. The Clod-Crusher.—A heavy, corrugated iron roller is useful for crushing the clods. When the soil is in large hard lumps or clods, the outside only of such clods can be acted on by the air and can be of use to the plant. By breaking the clods, we expose the surfaces of all the tiny particles to the

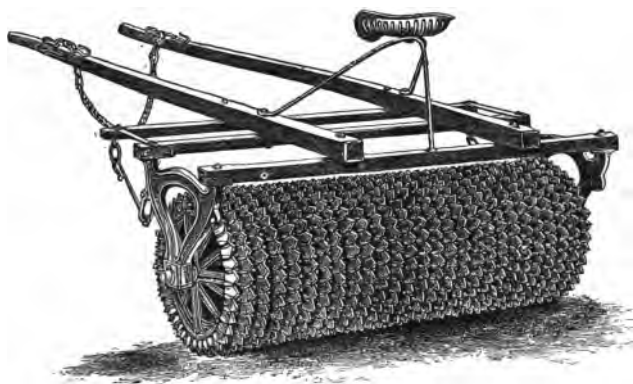


FIG. 17.—CLOD-CRUSHER.

air, and we offer all the plant-food they contain to the rootlets of the plant. No roller, however, can equal *frost* as a breaker-up of clods.

90. The Roller.—Wooden rollers are used to smooth the surface of the soil in which small seeds are about to be sown. Iron rollers, being heavier, compress the light soils at the same time that they level them. The compression of the soil prevents the small seeds from burying themselves too deeply in the ground.

When the soil is light, open, and dry, small seeds readily find their way down to a depth of two or

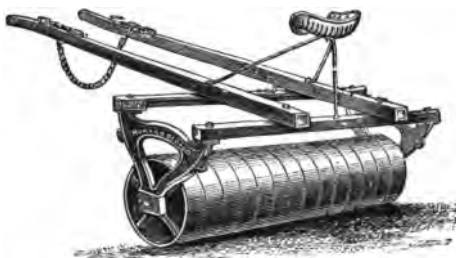


FIG. 18.—ROLLER.

three inches ; whereas they would grow better if they were just covered by the soil, hence the advantage of rolling the soil before sowing wheat, etc.

Winter-sown crops are often rolled with advantage in the spring, since the soil is thereby pressed closely to the roots.

91. **The Harrow.**—The harrow is used to complete

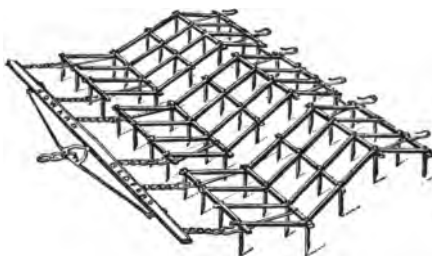


FIG 19.—HARROW.

the task of breaking up clods. It is also used to cover over newly-sown seeds.

The main object in using all these instruments is to turn over and stir up the soil in the best manner, with the least expense, and in the shortest time. Those who cultivate the soil have learned by experience that the surest way to obtain good crops is by thorough cultivation; but it is only of late years that they have discovered that one of the great reasons for doing so is that thereby dormant matter is changed into active plant-food.

XIII.—THE OBJECTS OF CULTIVATION.

(Continued.)

92. Cultivation destroys Weeds—93. Why Weeds are injurious—94. Cultivation allows the Plant to seek for Food—95. Cultivation protects the Crops from Injury by Animals—96. Cultivation is necessary to secure a good Seed-bed.

92. Cultivation destroys Weeds.—What is a weed? We may say that it is a plant in the wrong place. If we have prepared a field for wheat; if we have seen that it has in its soil a supply of plant-food such as wheat requires, and that everything is in a proper state to enable the wheat to grow well; and if we have carefully sown wheat in that field, then we consider any other plant which springs up with the wheat to be a weed. It may be oats or barley, it may be grass or tares, it may even be a beautiful garden flower; whatever plant it be, if it be not wheat, it is a weed, for it is out of its place in a wheat-field.

93. Why Weeds are injurious.—Weeds injure our crops in several ways. In the first place, they absorb some of the plant-food which has been prepared for the crop. What is enough for one may not be enough for two, and the plant-food which would have been sufficient for the true crop is not sufficient for both the true crop and the weeds.

Again, weeds keep air and sunlight from the crops, and the latter look sick and weakly in consequence. The hoe is an instrument much used for destroying weeds. On a good farm we shall be certain to see the land fairly *clean*, or free from weeds.

94. Cultivation allows the Plant to seek for Food.—Uncultivated soil is always more or less hard. Now, the rootlets of plants are soft and tender, and the roots themselves are not able to force their way easily through hard ground. But if a plant is to grow well, it requires abundance of food, and food of many kinds. The chemical analysis of plants shows that any ordinary plant contains about a dozen separate substances; and unless the plant can obtain all these, it cannot grow well. To obtain this variety of food, and to get enough of each kind, the roots of a plant may have to wander for a considerable distance through the soil; but they cannot do so if the particles of the soil are firmly joined together. By cultivation we make the soil open, we separate the particles from one another; the roots can then rapidly push through the soil, and the growth of the plant will be rapid and free. If we could see the distances to which roots extend, some downwards and some sideways, we should be greatly surprised. The roots of trees frequently extend as far out as the branches; while the roots of smaller plants often go below the surface to as great a distance as the stem rises upwards. The fact that the roots of many of the plants which form our crops will go down a distance of two feet

or more in search of food, ought to teach us to cultivate the soil *deeply*. We can increase our crops either by cultivating a larger area—a greater surface of land—or by cultivating the land we already have to a greater depth; but in the former



FIG. 20.—POTATO PLANT, SHOWING ROOTS.

case we shall have to pay an increased rent, while in the latter we shall get more produce from the same area. It may be that one acre of land cultivated deeply will produce as much as two acres of shallow soil. By better cultivation the value of the produce may be doubled, while the rent remains the same.

95. Cultivation protects the Crops from Injury by Animals.—The fences or hedges which enclose our fields serve not only to mark out their limits, but also to prevent either wild or tame animals—such as horses, pigs, dogs, deer, etc.—from entering at their will and damaging the growing crops.

The cultivation of the soil, moreover, destroys myriads of insects which would feed upon the crops. Beetles, flies, ants, etc., are crushed, their

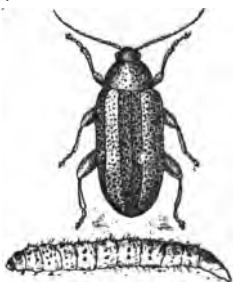


FIG. 21.—TURNIP-FLY, OR FLEA-BEETLE, AND LARVA.

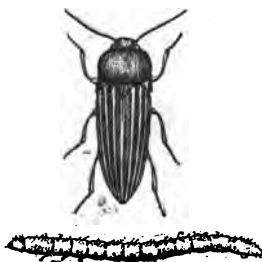


FIG. 22.—CLICK-BEETLE AND WIRE-WORM.

nesters are broken up, and their eggs destroyed by the implements used in turning over the soil, or by some of the manures, such as lime, which are added to the soil.

96. Cultivation is necessary to secure a good Seed-bed.—On virgin soil, it is a mere chance whether a seed falls on ground which is in the best state to receive it. For this reason most of the seeds of wild plants are wasted, because they fall on stony or unfit ground. By cultivation the farmer prepares a suitable seed-bed for his seeds, so that every seed will have a good chance of growing. We should en-

deavour, in preparing the seed-bed, to combine the firmness which is necessary to fix the plant in the soil and to support it, with the freedom or openness which will allow the roots to search far and near for food. Of course the smaller the seed, the more compact should the seed-bed be made by rolling ; otherwise little seeds may fall too deeply into the ground.

PART III.

THE CIRCUMSTANCES MAKING TILLAGE MORE OR LESS EFFECTIVE.

XIV.—FERTILITY OF THE SOIL.

97. Value of Scientific Knowledge to the Farmer—98. Natural Fertility of the Soil—99. Climate—100. The Injury done by "Pans."

97. Value of Scientific Knowledge to the Farmer.—In these days no one can hope to farm successfully who cannot give a reason for his successes and for his failures. If a man goes on doing as his father did before him, or as he sees people do elsewhere, but without knowing "the why and the wherefore," he must not hope to get the best return from his land. It is here that the value of scientific knowledge steps in. By the study of the science combined with the practice of agriculture, the farmer is able to see what is best to be done; and even if he fail, he will learn something from his failures. No one can control the seasons, or raise the price of agricultural produce; but the advantage of science is that it teaches us how to make the best of the former, and how to grow crops more cheaply, so that we

may make a fair profit even when we have to sell at a reduced price. It is certain that a knowledge of the science of agriculture is absolutely necessary if our tillage operations are to be as effective as possible.

98. Natural Fertility of the Soil.—No farmer can get out of the soil that which it does not contain. A naturally fertile soil is one that contains all the substances required for the growth of plants, and contains them in such a condition as to be available for the plant. In vain might we attempt to get a good crop of any kind from pure sand or from pure clay.

By the addition of manures we can make any soil artificially fertile, but the cost of the manure may be so great that the value of the crop will not repay it.

From a barren soil the most scientific farmer cannot expect to get good crops without manure. But science will teach us how best to improve the soil. By analysis we can find out in what materials the soil is deficient. By examining the subsoil in the same way we can tell whether it will be a good thing to bring much of it to the surface, and so to improve the soil by admixture, or whether the subsoil contains substances injurious to plants in too large quantities to admit of this being done. The success of tillage operations largely depends on the natural fertility of the soil; but science will help us to make the best both of rich soils and of poor soils.

Loamy soils are, as a rule, the most fertile and

easy to cultivate. Volcanic rocks, too, usually yield, by their decay, a very fertile soil. For this reason we find that the neighbourhood of a volcano, such as Vesuvius or Etna, is not avoided, as we might expect it to be, but that well-cultivated farms encircle these terrible mountains.

99. Climate.—The soil may be of the most fertile condition, yet it may be situated in a place where the climate will not permit of its being successfully tilled. The scientific farmer will soon ascertain what crops are best suited to the climate of any locality. He will take care to grow those crops, and to avoid planting others for which he knows that the climate is too hot or too cold, too wet or too dry.

When a farmer who has been accustomed to work by "rule of thumb" removes from one country to another, or even from one part of the same country to another, he may find, to his surprise, that the kind of tillage which suited the one place does not suit the other. But science teaches us that soils differ and that climates differ, and that our tillage operations must suit both the soil and the climate, if we hope for success. For example, with a clay soil and a heavy rainfall, a wise farmer will have much of his land in grass; while light land and a dry climate are well suited for turnips and barley.

100. The Injury done by "Pans."—A "pan" is a hard layer formed just between the soil and the subsoil. It acts injuriously by preventing the passage of air and of water through the ground, and by stopping the downward growth of roots. Pans are of different

kinds, and are formed in various ways. The most common kind is called *plough-pan*, because it consists of a compact layer of soil, the particles of which have been pressed together by the sole of the plough taking the same course year after year. *Lime-pans* are formed by the sinking of lime which has been applied as a manure. The lime cakes together and forms a tough, hard layer. *Iron-pans*, or moor-band

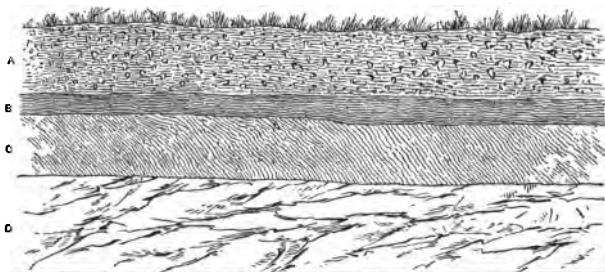


FIG. 23.—A, Soil; B, a Hard Layer or "Pan"; C, Subsoil; D, Rock.

pans, are formed by water containing much iron, which leaves the iron behind as it soaks through the ground.

To render the processes of tillage more effective, these "pans" ought to be broken up by deep cultivation. One of the great merits of steam-ploughing is that it stirs the land to a great depth—indeed, to the depth of as much as eight feet if required—thereby breaking up any pan which may have been formed.

XV.—DRAINAGE OF THE SOIL

101. Good Drainage is necessary—102. Annual Rainfall—103. How stagnant Water does Harm—104. Signs that Land needs Drainage—105. Can the Soil be over-drained?—106. Capillary Force—107. Stones in the Soil.

101. Good Drainage is necessary.—The soil cannot produce good crops if it is full of stagnant water. The removal of water from the land is called drainage, but drainage does much more for us than merely take away the water. As the water runs away, the air follows it and takes its place, and this does great good to the soil.

As rain falls through the air, it dissolves and brings down with it some of the gases which form the air, including oxygen, nitrogen, carbonic acid gas, ammonia, and nitric acid,—substances which are not only useful as plant-food, but which help to change some of the soil from the dormant to the active condition. Fishes breathe air dissolved in this way in water; and if they are placed in water which has been boiled and allowed to cool they die, because these gases have been driven out by the heat required to boil the water.

It is clear that the passage of rain-water through the soil must benefit the soil. If the water stand in the ground, the substances which it at first con-

tained will soon be used up, and it will not be able to yield a further supply of them to the soil.

The passage of water through the soil also washes injurious matters out of the ground. Lands which have been lately reclaimed, or recovered from the sea, have generally a soil too salt for the healthy growth of plants. If these lands are well drained, the continual passage of rain-water through the soil will, in a few years, wash out or remove the excess of salt.

Drains should be laid at a depth of from three to four feet, and they should slant steadily to their outfall, or the place where the water runs into the main drain or ditch. Stone drains are made by cutting trenches in the ground, putting broken stones in the bottom of the trench, and then replacing the earth. Pipe drains consist of round or oval porous pipes, made of baked clay, and about two inches in diameter. They are better than

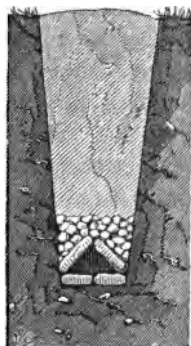


FIG. 24.—SECTION OF
STONE DRAIN.



FIG. 25.—DRAIN PIPE.

stone drains, since they do not so readily become choked up.

102. Annual Rainfall.—If all the rain which falls on the surface of Great Britain were to remain on the top of the ground, it would cover the land to a depth of three feet in the course of one year. Much of this rain, however, is evaporated by the sun; much runs

over the surface, forming rivers; but much also sinks into the ground. The passage of this rain-water does great good to the soil, for it brings with it plant-food, and also substances which change dormant into active matter. The great thing to be aimed at in good drainage is to secure this frequent flow of water through the land.

103. How stagnant Water does Harm.—Stagnant water—that is, water at rest—fills up the pores of the soil, and effectually prevents any more water entering. Not only does it prevent the entrance of fresh water; it also keeps out the air. Stagnant water, further, chills the soil, and this greatly retards the growth of plants, which like a rather warm bed in which to germinate and grow. This chilling is effected in various ways. For instance, it is well known that water evaporates at all temperatures, and that it requires heat to change it from the state of liquid water into that of water-vapour, or steam. If we place a drop of water on the back of the hand it will soon evaporate, and the skin will feel cold: the reason is that the heat required to evaporate the water has been taken from the skin. In just the same way the stagnant water in undrained land evaporates, and takes heat away from the soil.

Then when the sun shines on the soil the surface water absorbs the heat; but, since water is a very bad conductor of heat, the warmth does not pass downwards. If we were to try to boil water by lighting a fire on the top of the kettle that holds it, we should find the surface of the water become warm, but the heat would not pass downwards,

and we should never get the water at the bottom to boil. The stagnant water in the soil remains cold for the same reason.

We may also add that when the soil is full of water, all the rain which falls has to run over the surface of the land, and in doing so it washes away the manure and the fine particles of soil into ditches and streams, and so does much injury. On well-drained land the rain soaks in, and the manure and the fine surface-soil are not thus washed away. It has been justly remarked that we drain land as much to get (fresh) rain-water into it as to get (stagnant) rain-water out of it. Well-drained land is also much easier to work, so that fewer horses are needed for ploughing, etc. The presence of much water makes the soil very stiff and hard to move.

104. Signs that Land needs Drainage.—On undrained land the snow lies long, and mists are often seen rising from the ground. A thermometer buried a foot deep in ill-drained soil indicates eight or ten degrees of greater cold than another thermometer buried to the same depth in well-drained land. Rushes, sedges and reeds, docks and thistles, the flowers of the spotted orchis and the little mounds of tussock grass, indicate ground full of standing water. All these weeds will disappear from thoroughly drained land. Badly drained land grows but poor crops; the straw is short and has a blighted appearance, while the herbage looks thin and “wiry.”

105. Can the Soil be over-drained?—We know that it is possible to have too much of a good thing; and so it is possible on shallow soils to over-drain the

land, and not to leave enough of moisture in the soil for the use of the growing crops. But on most farms, where there is a good depth of soil and subsoil, we need not fear anything of the kind. The fact is, that it is very seldom that drains can be put in deeper than three or four feet, and all the subsoil below this depth cannot therefore be drained by the pipes or drain-tiles put in. But will the water, at a depth of four feet, be of any use to roots which do not go down deeper, say, than two feet? The reply is, that the water does not remain deep in the subsoil: if the soil be well drained and dry, and the subsoil full of moisture, then the water will *rise* through the pores, or little spaces between the particles, of the soil, to a height of from two to four feet.

106. Capillary Force.—The rise of the water in open or porous soils is said to be caused by *capillary force*. If we notice the water in a drinking glass, we shall see that the fluid stands a little higher where it touches the sides than in the middle of the vessel: this is because the water adheres to the glass. If we put a narrow glass

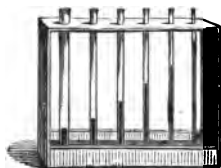


FIG. 26.—Rise of Water in Narrow Tubes.

tube into the water, we shall see the water rise an inch or more within the tube; and if we use a tube fine as a hair, the water may rise in the tube as much as a foot higher than the water outside.

The force which causes liquids to rise in narrow tubes is called *capillary force*, from the Latin word *capillus*, a hair, because it acts best in tubes fine as hairs. The pores in a soil form

irregular narrow tubes, and up these tubes the water rises from the subsoil below. In this way, during hot, dry summers, the roots of plants in deep, well-drained land get a steady, regular supply of water from below.

Since the pores in clay are much smaller than those in sand, the capillary force will raise water from a greater depth in clayey than in sandy soils. If we take two glass tubes, each about an inch in diameter and four feet in length, and fill one with dry clay and the other with dry sand, and then place the two tubes upright and side by side in a glass of water, we shall be able to see how the capillary force acts in each substance. We shall see the water slowly creep up the clay to a height of perhaps three feet. In the sand the rise of the water will be more rapid, but it will not reach higher than from twenty-two to twenty-four inches.

107. Stones in the Soil.—Stones are not injurious to the soil, so long as they are of a moderate size and not too numerous. Sometimes, in ploughing, immense stones are found, weighing several hundred-weight, or even tons, formed of a kind of rock which does not occur in the neighbourhood. These great boulders have been transported (see p. 42) from a distance, in ages long gone by, before man lived in Britain, by the action either of icebergs or of glaciers. Stones of moderate size are useful in retaining moisture in the soil: in hot dry weather, if we turn over a stone, we shall be certain to find the soil underneath it damper than elsewhere. They also help to warm the soil, and render it opener and

easier of tillage. They contain a supply of plant-food, which they will yield when broken up. On very light sandy lands, stones are useful in preventing the small dry grains of the soil from being blown away. On the whole, it may be said that so long as the proportion of stones does not exceed one-tenth of the bulk of the soil, they are rather useful than otherwise. It is a good plan to have the larger stones broken up, from time to time, and the fragments left on the soil.

XVI.—IMPORTANCE OF AUTUMN CULTIVATION.

108. Clean the Land in Autumn—109. Plough the Land in Autumn—110. Stir the Subsoil in Autumn—111. The exposed Soil absorbs Ammonia—112. Comparison of Soils.

108. Clean the Land in Autumn.—After the main crops have been removed in autumn, we have a favourable opportunity for thoroughly cleaning the land by removing the weeds which, if left, would rob the soil of plant-food. In autumn the weeds are comparatively weak, and are easily destroyed. They should then be removed by the hoe and the grubber, piled up in heaps, and burnt, the ashes being spread over the soil, which they will help to fertilize.

109. Plough the Land in Autumn.—We have seen that in olden times it was the custom to allow the land to remain idle or fallow at frequent intervals, in order that it might recover the fertility of which it had been deprived by repeated crops. The crops which had been taken out of the soil had absorbed all the plant-food which the soil then contained, and the soil had thus become barren; but after lying fallow for a year, and still more after lying

fallow for several years, the soil was found to have recovered the power of growing a crop, so that plant-food must have entered it from some source or other. We now know that this change was due to some of the dormant matter of the soil being converted into active matter (that is, into plant-food) by the combined action of frost, air, and rain.

Farmers have now given up the plan of allowing the land to lie fallow for years, but they still, for the most part, allow it to lie fallow during the winter months; for during that part of the year there is so little sunshine, and so much frost, rain, and snow, that it would be useless to expect crops to make much growth.

Now this winter-time, during which the land lies bare and exposed to the weather, ought to be used by the farmer to the best advantage. If he allows the soil to lie flat and compact, the frost, air, and rain can act only on the outside—on the level surface which is exposed. He must therefore break it up, so as to present as large a surface as possible to the influences of the atmosphere.

110. Stir the Subsoil in Autumn.—With this view, the farmer ought to plough his land deeply in autumn. He should throw the soil into ridges, by which he will double the extent of the surface exposed to the weather. At the same time he should stir the subsoil deeply with the grubber, and bring up more or less of the subsoil to mingle with the surface soil. Perhaps the subsoil contains substances which are injurious to crops; but after they have been acted on by the severe weather of

the winter months—after oxygen has come in contact with them, and rain-water has washed them, and frost has broken them up into small particles—these injurious substances will be converted into matter useful for plant-food.

After a severe winter, the entire surface of an autumn-ploughed field will be found covered with the finest mould, the result of the breaking up of the clods by the frost. This fine mould will form an excellent seed-bed, and the farmer should be careful not to plough it in. The field may be lightly harrowed or rolled, but, as a rule, it should not again be ploughed before the seed is sown.

111. The exposed Soil absorbs Ammonia.—Another reason for ploughing the land deeply in autumn, and leaving it bare and exposed during the winter months, is that during that time it will be enriched by the addition of ammonia from the air. Ammonia is a most valuable plant-food. If it had to be purchased, it would cost the farmer £100 per ton; but if the farmer will go to work in the right way, he will obtain some ammonia from the air free of expense. The double silicates of the soil are especially useful in absorbing ammonia, and soil which is rich in these double silicates will store up ammonia during the period of its winter exposure, and will hold it ready for the use of the next crop. From this we see that it is heavy or clayey soils that benefit most by winter exposure, since they contain most of these double silicates. Light, free, sandy soils, which are already disintegrated or thoroughly broken up, require a very different treatment from heavy, stiff, clayey soils.

112. Comparison of Soils.—The two great classes of soil may be compared as follows:—

LIGHT SOILS.

1. Composed chiefly of silica and lime.
2. Dry in character; neither absorbing nor retaining much moisture.
3. Require little draining.
4. Warm, loose, and friable.
5. Made more compact by the addition of marl or clay.
6. Grow turnips and barley well.
7. Improved by rolling.
8. Manure in spring.
9. Plough in spring.
10. Feed off root-crops on the land in winter.

HEAVY SOILS.

1. Composed chiefly of silicate of alumina.
2. Wet in character; absorbing water and holding it.
3. Much improved by draining.
4. Cold, compact, and close.
5. Made more open by the addition of sand and lime.
6. Grow wheat and beans well.
7. Clod-crushers useful.
8. Manure in autumn.
9. Plough in autumn.
10. Cart off any crops of roots that may have been grown.

XVII.—THE MECHANICAL CONDITION OF THE SOIL.

113. Successful Farming demands Experience—114. Experience enables us to judge of the Mechanical Condition of the Soil—115. Terms used to describe Mechanical Conditions of Soils—116. Cause of "Sickness" in Soils—117. Cure for Soil-Sickness—118. Comparison of fertile and barren Soils.

113. Successful Farming demands Experience.—The study of science alone will not enable any one to cultivate the soil successfully. The best course of training is that which combines practical with scientific work. Many men, who knew nothing of science, have been very successful farmers, because they were placed in favourable conditions, having fertile soil and sunny seasons, and especially because, having spent all their life in one district, perhaps on one farm, they had learned by experience what practice would yield good results. It is now usual for young men who have been some years at college learning the science of agriculture, to place themselves for a year or two, after leaving college, with some skilful and successful farmer, in order that they may acquire experience before they begin to farm for themselves.

114. Experience enables us to judge of the Mechanical Condition of the Soil.—By chemical analysis we can

learn of what substances the soil is composed, and by separating the soluble from the insoluble part we can even find out how much plant-food the soil contains. Then by mechanical analysis we can separate, by washing, the sand from the clay, and learn how much of each the soil contains.

From these two analyses we can learn a great deal about the soil, but they alone will not teach us how to farm a piece of land successfully.

A good farmer ought to be well acquainted with the *mechanical condition* of his soil. He ought to know when it is in the right state for sowing or planting the various crops, and whether any portion is not sufficiently drained. In fact, from his daily experience he ought to learn how to manage every field so as to produce the best results. There are perhaps no two fields in Britain the soil of which is exactly alike. Every student of agriculture must carefully study the soil with which he has to deal. He will find it a subject of the greatest interest. He will find that soils have their characters and dispositions, their tempers and moods, the knowledge of which is essential to their successful cultivation.

115. Terms used to describe Mechanical Conditions of Soils.—The terms *tough* and *obstinate* are often applied to clayey soils, but these soils do not deserve such names unless they are wrongly treated. No amount of spring cultivation will reduce clay clods to the same fine powdery mould to which they are readily brought by the frosts of winter. All stiff clays should be ploughed deeply and

roughly in autumn, and left bare and exposed till spring.

Sometimes the farmer cross-ploughs in spring his autumn-ploughed fields, thereby burying the fine surface-soil and bringing up fresh clods. This is generally a bad plan ; but if, for any reason, spring-ploughing be necessary, then the farmer should watch his fields, and try to catch the right moment, just when the clods have been softened by a shower of rain, and harrow the soil ; the clods, being in a tender condition, will then often fall to pieces.

Clayey soils become hard and *baked* by long-continued dry and hot weather. They then *crack* in all directions. A farmer should endeavour to *lighten* and improve these stiff clays by the admixture of organic matter, sand, lime, or burnt clay. Soils which are good in themselves, but which require much experience and management on the part of the farmer, are said to show *temper*.

Barren soils, such as pure sands, are sometimes called *ungrateful*, because they often give little or no return for all the care expended on them or the manure put into them. Sandy soils have little power of *retaining* manure, but allow it to be washed away by rain. Fertilizing matters, however, cling to the particles of clay, and so are held in the pores of clayey soils, ready for the use of plants.

Loamy soils are generally pleasant to manage, being easy of cultivation, and giving good returns for the care and trouble expended on them ; they are therefore called *kindly*, *grateful*, and *generous*.

In short, we may say that soils have their char-

acters and dispositions just as much as animals have. No book can teach the student how to recognize these characters or to find out these dispositions—no book at least except the book of nature.

116. Cause of "Sickness" in Soils.—Sometimes the soil of a certain field will not grow good crops. In vain the farmer heaps "muck" upon it; in vain he ploughs it, and sows the best seed. The plants that do spring up are stunted and feeble, and at best perhaps half a crop rewards the farmer's care. What can be the cause of this?

First, some injurious substance may be present in the soil. An excess of salt or of iron often prevents healthy growth. The remedies for this are usually drainage and deep ploughing. The passage of water through the soil will in time wash away the injurious matters, while the entrance of air may even change these harmful substances into useful ones.

Secondly, the soil may lack some ingredient which is a necessary plant-food. If a plant is to thrive, it must have all that it requires. We cannot make up for the want of one kind of food by giving double the quantity of another kind. It is the same with animals. Man, for example, requires a little salt—about a quarter of an ounce—daily. If we were to supply a man with food perfectly free from salt, he would suffer severely, and at last would die. So it is with plants. They want ten or twelve kinds of substances for their daily food, and if they are deprived of any one of these substances, they will not grow. This is now so well

understood that it is considered as a law in the science of agriculture that "it is those portions of plant-food which are least abundant in the soil that determine its fertility."

The cause of this second kind of soil-sickness is usually the exhaustion of the land by the removal from it of crop after crop, without a proper return being made to the soil. Thus an average crop of wheat will take away from an acre of land 102 lbs. of silica; and it is clear that if we go on growing wheat year after year on the same land, we shall remove nearly all the soluble silica. But the wheat plant is quite unable to grow without a good supply of silica; and we should find, after three or four years of continuous wheat-cropping, that an ordinary soil, to which nothing in the meantime had been added, would refuse to grow good crops of wheat: we should then say that the soil was "sick" of wheat.

117. Cure for Soil-Sickness.—If we now allowed this "sick" land to lie fallow for a time, it might again give us a good wheat crop. During the time it was fallow, the air, rain, and frost—atmospheric agencies, as they are called—would be acting on it, and changing some of its insoluble or dormant silica into a soluble or active state.

But there are other crops, such as beans, which require but little silica, and the land might still grow these although it could not grow wheat.

A good farmer knows how to prevent the soil of his farm from becoming exhausted in this way; indeed, good farming does even more than this

—it makes the soil more productive year after year.

118. Comparison of fertile and barren Soils:—

BARREN SOIL.	FERTILE SOIL.
1. Lacks, at least, one necessary plant-food.	1. Contains <i>all</i> the necessary kinds of plant-food in abundance.
2. Often composed of one substance only,—as pure sand, pure clay, peat, etc.	2. Composed of a mixture of substances.
3. Often shallow, resting on bare rock.	3. Generally deep, resting on good subsoil.
4. Often very light (or yellow) colour.	4. Generally dark (or red) colour.
5. Pores large, but few.	5. Pores numerous and small.
6. Sometimes contains injurious substances,—as an excess of salt, the lower oxide of iron, sulphate of copper (green vitriol), etc.	6. Contains no substances injurious to plants.
7. Often ill drained.	7. Drainage good.
8. Presence of a “pan.”	8. No “pan” present.
9. Contains either very little organic matter (as in pure sand), or an excess of it (as in peat).	9. Contains a moderate amount of organic matter.
10. Stones very numerous, forming more than one quarter of the soil.	10. Stones few.
11. Requires much manure.	11. Requires, as manure, only those substances which are removed in the crops.

A farmer who knows nothing of the science of agriculture may grow crops successfully on a fertile soil; but if the soil be barren, it will require not only hard work but forethought and knowledge to make it yield good results.

APPENDIX.

QUESTIONS ON THE PRINCIPLES OF AGRICULTURE.

FIRST STAGE.

1. What does the science of agriculture teach?
2. How does a knowledge of science help a man to farm?
3. What is an experiment?
4. What are the three main objects to be aimed at in farming?
5. Name the four sciences of which a knowledge would be most useful to a farmer.
6. What is an element? Name any elements you know.
7. Why is water called a compound? In how many states can water exist?
8. What is the composition of common salt, and red iron-rust?
9. What is the name of the science which treats of the nature and origin of rocks?
10. Name all the different kinds of rocks which you know. What do you call rocks which have been formed at the bottom of seas or of lakes?
11. Of what elements is limestone composed? How could you tell limestone from any other rock?
12. Of what use would a geological map be to a farmer?
13. Classify the following substances into organic and inorganic matter—coal, bread, slate, iron, farm-yard manure, sand, straw, wood, water, leather.
14. Name the three kingdoms of nature, and give three examples of each.
15. What do you mean by an organized being? Has a horse, or a rose, any organs? If so, name them.
16. To what height does the air extend, and how heavily does it press on the surface of the earth?

17. Which is the most important gas in the air? Of which gas is there the largest quantity?

18. How many gallons of carbonic acid gas would be contained in 20,000 gallons of air?

19. What substances does the air contain which are easily washed out of it by rain?

20. How would you prove to any one that the air always contains some water?

21. What does a farmer manufacture, and what is the raw material which he uses called?

22. From what has the soil been formed?

23. What is the subsoil? How could you get some of it?

24. Name all the agents which have helped to form the soil.

25. Would a stone building last longer in a dry country or in a wet country? Give a reason for your answer.

26. Explain how frost, water, and air help each other to break little fragments off hard rocks.

27. What do you call soils which have removed many miles from their parent rocks? What was it that removed them?

28. How do you account for there being so many different kinds of soils?

29. Describe peat. How was it formed?

30. Describe a clayey soil.

31. Describe a sandy soil.

32. What is the weight of one cubic foot of sand and of clay respectively? Which of these soils would a farmer call "light"?

33. Compare the porosity and the absorbing powers of sand and of clay.

34. How could you tell exactly how much sand the soil of a certain field contained?

35. How would you find out what weight of organic matter the soil of a field contained?

36. What is silica, of what elements is it composed, and what effect has water upon it?

37. What is the chemical composition of pure clay?

38. What are double silicates? Name some.

39. Name any mineral substances in the soil which are able to act as plant-food.

40. What is the composition of phosphate of lime?

41. What is the composition of a calcareous soil?

42. Why does pure sand form a barren soil?

43. Give a reason for thinking that all soils have been derived from the breaking up of crystalline rocks.

44. How could you tell, by its appearance, whether or not a soil was rich in organic matter?

45. What do you mean by the word *humus*? Where does the humus in soils come from?
46. How should the chemical analysis of the soil be conducted in order to be really useful to the farmer?
47. Explain the word *dormant*. To what part of the soil is it applied?
48. Is the dormant matter of the soil ever changed into the active state? By what agencies is the change effected?
49. How may a farmer render the change of dormant into active matter more rapid and complete?
50. The dormant matter of the soil is said to be of great use even while it remains dormant: explain its use.
51. Why does a cultivated field bring forth better crops than a field that is uncultivated?
52. Name all the implements you know which are used in the cultivation of the soil, and explain the use of each.
53. What is a weed? How do weeds injure crops?
54. Why do plants thrive better when the soil is loose and open than when it is hard and compact?
55. Explain how climate influences farming.
56. What are "pans"? How are they formed?
57. What do you know about capillary force?
58. Point out the benefits to the soil which result from thorough drainage.
59. What is the best season of the year in which to clean and plough the soil? Give your reasons.
60. Double silicates have been called "nets to catch plant-food:" explain this.
61. Soils are sometimes called "sick." Name any common cause of sickness in soils, and say how you would remedy it.
62. What are the qualities of a fertile soil?



EXAMINATION PAPERS.

I.

1. What substances are found in our soils, and which of them do plants feed upon?
2. Why do we drain some of our soils, and what advantages do we gain by doing so?
3. How is it that a thoroughly good tillage of the soil makes the land more productive?
4. What is the difference between a sandy soil, a loamy soil, and a clayey soil?

II.

1. As the soil very largely consists of hard, solid matter, how is it that plants are able to feed upon it?
2. Why are soils improved by exposure to rough and cold weather in the winter?
3. How do soils become exhausted and unable to produce good corn crops?
4. How are soils formed?

III.

1. Mention the various kinds of soils, and the manner in which you would distinguish them from each other.
2. Describe the capillary powers of a soil, and show how the fertility of the soil is influenced thereby.
3. What do you mean by the mechanical analysis of a soil? How would you carry it out, and of what use is it?
4. Explain the words *subsoil*, *humus*, *soluble*, *element*, *compound*, and *germinate*.

THE END







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